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US Department of Transportation
Federal Aviation Administration

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Office of Aviation Policy and Plans
Washington, D.C. 20590

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Ward L. Keech

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16. Abstract

Drawing on economic theory, empirical investigations and data from government, private and academic literature, this report updates economic values commonly used by the Federal Aviation Administration in the evaluation of investment and regulatory programs. These values, commonly referred to as "critical values," provide the basis upon which the effectiveness of the aviation system or changes therein may be denominated and assessed in monetary terms. The critical values updated in this report include the value of time of air travelers, the value of a statistical life, unit costs of statistical aviation injuries, unit replacement and restoration costs of damaged aircraft, and aircraft variable operating costs.

The values developed in this report are expected to change with the passage of time because of anticipated price and income level changes and, to a lesser extent, future theoretical and empirical research. Periodic revisions of this report will attempt to account for such changes and advancements. Between interim revisions, users may desire to adjust the values developed herein to future year dollars based on the methodology outlined in the appendix to this report.

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TABLE OF CONTENTS

SECTION		PAGE
	EXECUTIVE SUMMARY	i
I.	VALUE OF TIME OF AIR TRAVELERS	1
	A. Introduction	1
	B. Theory of the Valuation of Time in Travel	2
	1. Business Travel	2
	2. Nonbusiness Travel	2
	3. Generalized Theory of the Value of Time	3
	C. Empirical Approaches to the Valuation of Time in Travel	4
	1. Labor Product Approach	4
	2. Willingness-to-Pay Approach	7
	D. The Issue of Multiple Valuation of Time	9
	E. Summary	10
II.	VALUE OF A STATISTICAL LIFE	12
	A. Introduction	12
	B. Human Capital Approach	12
	C. Court Awards Approach	13
	D. Willingness-to-Pay Approach	14
	E. Value to Self and Others Approach	14
	F. Summary	26
III.	UNIT COSTS OF STATISTICAL AVIATION INJURIES	30
	A. Introduction	30
	B. Court Awards Approach	30
	C. Willingness-to-Pay Approach	30
	D. Value to Self and Others Approach	31
	E. Summary	37
IV.	UNIT REPLACEMENT AND RESTORATION COSTS OF DAMAGED AIRCRAFT	41
	A. Introduction	41
	B. Air Carrier	41
	C. General Aviation	42
	D. Military	43
	E. Summary	51
V.	AIRCRAFT VARIABLE OPERATING COSTS	52
	A. Introduction	52
	B. Air Carrier	53
	C. General Aviation	53
	D. Military	53
	E. Summary	66
VI.	APPENDIX: ADJUSTMENT METHODOLOGY TO UPDATE CRITICAL VALUES	67
VII.	FOOTNOTES AND REFERENCES	70

EXECUTIVE SUMMARY

Drawing on economic theory, empirical investigations and data from government, private and academic literature, this report updates economic values commonly used by the Federal Aviation Administration in the evaluation of investment and regulatory programs. These include the value of time of air travelers, the value of a statistical life, unit costs of statistical aviation injuries, unit replacement and restoration costs of damaged aircraft, and aircraft variable operating costs.

These values and others, often referred to as "critical values," provide the bases upon which the effectiveness of the aviation system or changes therein may be denominated and assessed in monetary terms. FAA decisionmaking should ideally discriminate among alternative investment and regulatory actions according to whether or not they involve socially and economically acceptable uses of user and general taxes. Conceptually, these values can be thought of as measures of the minimum dollar sacrifice that society and users are or should be willing to make to provide for the sustained or improved effectiveness of the aviation system.

Whereas some critical values are readily measurable by reference to the marketplace, others must be imputed and are subject to estimating error because of state-of-the-art and data limitations. Nevertheless, analyses must be conducted and decisions made. Even imputed dollar estimates of benefits gained or foregone will guide and facilitate rational and intelligent FAA decisionmaking. This basis is obviously preferable to decisionmaking based merely on subjective or intuitive judgment.

The critical values developed in this report are summarized below in terms of 1980 dollars. These values are expected to change with the passage of time because of anticipated price and income level changes and, to a lesser extent, future theoretical and empirical research. Periodic revisions of this report will attempt to account for such changes and advancements. Between interim revisions, users may desire to adjust these values to future year dollar levels based on the methodology outlined in the appendix to this report.

NATURE OF CRITICAL VALUE	1980 VALUE
Value of Time of Air Travelers Per Hour	$ 17.50
Value of a Statistical Life	$ 530,000
Unit Costs of Statistical Aviation Injuries:	
Serious Injury	$ 38,000
Minor Injury	$ 15,000

Unit Replacement/Restoration Costs of Damaged Aircraft (Replacement or Destroyed/ Restoration or Substantial Damage):	Replacement Cost	Restoration Cost
Air Carrier:		
-Turbofan, 4 Engine, Wide Body	$20,500,000	$6,800,000
-Turbojet, 4 Engine	$ 1,600,000	$ 530,000
-Turbofan, 4 Engine, Regular Body	$ 4,000,000	$1,300,000
-Turbofan, 3 Engine, Wide Body	$20,500,000	$6,700,000
-Turbofan, 3 Engine, Regular Body	$ 4,000,000	$1,300,000
-Turbofan, 2 Engine, Wide Body	$20,000,000	$6,700,000
-Turbofan, 2 Engine, Regular Body	$ 5,100,000	$1,700,000
-Turboprop, 2 Engine	$ 1,300,000	$ 430,000
-Piston, 2 Engine	$ 300,000	$ 100,000
-Total Air Carrier	$ 6,200,000	$2,100,000
General Aviation:		
-General Aviation in the conventional sense (including Air Taxi and Air Commuter)	$ 59,000	$ 20,000
-General Aviation including Air Taxi other than Air Commuter	$ 58,000	$ 19,000
-General Aviation excluding Air Taxi	$ 56,000	$ 19,000
-Air Taxi	$ 137,000	$ 46,000
-Air Taxi other than Air Commuter	$ 120,000	$ 40,000
-Air Commuter	$ 213,000	$ 71,000
Military:		
-Fixed-Wing	$ 2,200,000	$ 730,000
-Rotary-Wing	$ 410,000	$ 140,000
-Total Military	$ 1,400,000	$ 470,000

Aircraft Variable Operating Costs:	Per Block Hr.	Per Airborne Hr.
Air Carrier:		
-Turbofan, 4 Engine, Wide Body	$ 4,327	$ 4,767
-Turbojet, 4 Engine	$ 2,483	$ 2,880
-Turbofan, 4 Engine, Regular Body	$ 2,295	$ 2,643
-Turbofan, 3 Engine, Wide Body	$ 2,897	$ 3,341
-Turbofan, 3 Engine, Regular Body	$ 1,641	$ 1,964
-Turbofan, 2 Engine, Wide Body	$ 2,155	$ 2,655
-Turbofan, 2 Engine, Regular Body	$ 1,219	$ 1,508
-Turboprop, 2 Engine	$ 546	$ 694
-Piston, 2 Engine	$ 136	$ 139
-Total Air Carrier	$ 1,871	$ 2,229
General Aviation:		
-General Aviation in the conventional sense (including Air Taxi and Air Commuter)		$ 81
-General Aviation including Air Taxi other than Air Commuter		$ 79
-General Aviation excluding Air Taxi		$ 73
-Air Taxi		$ 163
-Air Taxi other than Air Commuter		$ 145
-Air Commuter		$ 278
Military:		
-Turbojet/fan, Multi-engine		$ 2,339
-Turbojet/fan, Twin-engine		$ 1,319
-Turbojet/fan, Single-engine		$ 872
-Turboprop		$ 360
-Piston		$ 97
-Rotary-wing		$ 113
-Total Military		$ 661

SECTION I - VALUE OF TIME OF AIR TRAVELERS

A. Introduction

The purpose of this section is to derive a revised estimate of the value of time of air travelers for use in evaluating FAA investment and regulatory programs which bear on time spent in air travel. Since speed is the principal advantage of air transportation over alternative modes, the value of time can be a key ingredient in arriving at economically rational investment and regulatory decisions in the aviation system.

Time, in the sense used here, is realized by travelers in two ways. First, reduced enroute time makes more time available at origin or destination. Second, time is "saved" for many travelers if scheduled operations are made more reliable. More reliable schedules reduce the allowances for delay which prudent travelers make in planning trips. Conceptually, the value sought here is the gain to travelers, to other individuals, and/or to society resulting from reduced delays/decreased time enroute and more reliable schedules.

Because time is scarce, it is an economic good and has value. Time spent in business travel has value because wages or salaries are being paid by an employer. A saving of such time permits the employee to direct his time to other or more production activity. It can be argued that time spent in non-business or leisure travel has value because the traveler can alternatively use that time in some other activity in which he may derive greater or lesser utility.

There is no unique value of time. Its value varies among individuals as a function of several attributes, including income, earnings rate, age, education and family composition. Further, the value of time in travel for a given individual may vary with the purpose of the trip, length of trip, travel urgency, utility generated by the trip, time of day, or season. For these reasons and because of the imprecise art of valuing time, empirical investigations on the subject have suggested a dispersion of values, as evidenced by the following quotations:

> "...on _a priori_ grounds the value placed on travel time would be expected to vary directly with the hourly earnings opportunities of the traveler."[1]
>
> "There is every reason to believe that business travelers value their time in excess of earnings... There are also good arguments that can be made that nonbusiness travelers also place a value on their time greater than earnings."[2]
>
> "We could not find any systematic relationship between the passenger's income and the value he assigns to his time when he is on a personal trip. The estimated price of time of business travelers is consistently found to equal about forty per cent of their wage rate, a result

which agrees very well with some other estimates in this field."[3]

The remainder of this section addresses the theory of time valuation, various empirical approaches to the estimation of the value of time in air travel, the issue of multiple valuation of time, and lastly, a summary supporting a revised estimate of the value of time of air travelers for use in FAA investment and regulatory decisionmaking.

B. Theory of the Valuation of Time in Travel

1. Business Travel

The most generally accepted theoretical basis for valuing time in business travel is based on the theory of marginal productivity. It provides the customary backing for most approaches which estimate the value of time with reference to an earnings rate. The theory holds that, given the assumption of a profit-maximizing firm operating in perfectly competitive markets, the firm will be in equilibrium when the marginal product of a factor of production equals its price. Using labor as an example, the profit-maximizing firm will hire labor up to that point beyond which it is no longer worthwhile, i.e., where the marginal product of that labor equals its earnings rate. The value of an employee's time to a firm in equilibrium, therefore, is the employee's earnings rate or marginal product. Savings in travel time enable the employer to use the manhours released for additional productive purposes. Conversely, delay in travel time during business hours represents additional costs to the firm to the extent of the foregone productivity or the opportunity cost of labor.

This approach is sometimes criticized because economies in reality are substantially different from the perfect competition model upon which the theory is based. Nevertheless, the use of marginal and average earning rates as values of working time is widespread.

2. Nonbusiness Travel

Theoretical support for valuing time in nonbusiness travel normally rests on consumer-choice theory. The theory holds that, in equilibrium and in the absence of any market imperfections, consumers will allocate their time between different activities in such a manner that the marginal value of time is equal in each activity. As applied to travel, the theory holds that consumers will allocate their time between work, travel and other activities in such a way that the marginal value of time is equal in all activities. Therefore, if the marginal earnings rate represents the marginal value of time spent in work, then the value of time spent in all activities, including travel, will equal the marginal

earnings rate. Thus, the theory provides a basis for proposing that both business and nonbusiness travel can be valued at the earnings rate.

As with the theory of marginal productivity, consumer-choice theory can be criticized on the grounds that the assumptions upon which the theory is based are often violated in real economies. Nevertheless, consumer-choice theory often serves as the basis for valuing time in nonbusiness travel.

3. Generalized Theory of the Value of Time

Because of the weaknesses of traditional economic theory, there have been recent attempts to develop a more generalized theory of the value and allocation of time. The most far reaching of these attempts are those of Becker[4] and Groneau[5]. Their formulations hypothesize that the initial source of utility is the activity and that time is part of the individual's consumption decisionmaking process. Each activity involves the combination of purchased goods or services, the individual's time and (sometimes) intermediate activities. For example, the activity "visit to another city" might involve the cost of accommodations and food, time spent in that city and the activity travel. The individual attempts to maximize the utility derived from all activities that he engages in subject to budget and time constraints. The maximization of the utility function subject to these constraints yields the optimum allocation of time and goods and the value that the individual places on his time.

The novelty of the theory is reflected in Becker's idea of dropping separate goods and time constraints:

> ". . . and substituting one in which the total resource constraint necessarily equalled the maximum money income achievable, which will be called "full income." This income could in general be obtained by devoting all the time and other resources of a household to earning income, with no regard for consumption. Of course, all the time would not usually be spent "at" a job: sleep, food, even leisure are required for efficiency, and some time (and other resources) would have to be spent on these activities in order to maximize money income. The amount spent would, however, be determined solely by the effect on income and not by any effect on productivity... Households in richer countries do, however, forfeit money income in order to obtain additional utility, i.e., they exchange money income for a greater amount of psychic income. For example, they might increase their leisure time, take a pleasant job in preference to a better-paying unpleasant one. . . In these and other situations the amount of money income forfeited measures the cost of obtaining additional utility. Thus the full income approach provides a meaningful resource constraint

and one firmly based on the fact that goods and time can be combined into a single overall constraint because time can be converted into goods through money income..."[6]

The theory concedes that an average earnings rate will serve as only a very crude approximation of the value of time. The value of time may differ from the average earnings rate because of such factors as the difference between the average and marginal earnings rate, the marginal utility/disutility of work, the marginal utility/disutility of travel, engaging in other activities while traveling, institutional work hour standards, nonpecuniary (nonmoney) compensation, etc. Statistical estimation must be relied on to evaluate the extent of the divergence of the value of time from the average earnings rate.

C. Empirical Approaches to the Valuation of Time in Air Travel

There exists little general agreement in the results of the value of time in travel derived from empirical evidence. Figure I reflects the wide range of time values in air travel representative of those used over the past few decades. Most of these studies did not involve independent research on the value of time in air travel, but rather simply accepted values which were thought to be representative of current thinking and opinion.

In general, the various techniques that have been developed to empirically estimate the value of time in travel can be classified into two approaches: the labor product approach and the willingness-to-pay approach. Both approaches are briefly described below. Additionally, some of the more notable contributions to the valuation of time in air travel, in particular, are briefly summarized.

1. Labor Product Approach

As discussed above, neoclassical theory suggests that individuals with unconstrained labor-leisure choices will be best off when they allocate their time between activities in such a manner that the value of the last hour of time spent in each activity equals their earnings rate. Upon this basis, the labor product approach estimates the value of time as the contribution to the national product per employee work hour. The total contribution of labor to the national product is derived by subtracting from the gross national product all capital consumption allowances, indirect business taxes, rental income, net interest, corporate profits before taxes and inventory reductions. The quotient of labor's total contribution divided by total labor hours represents the average hourly contribution of labor to the national product. Since labor is presumed to be allocating its time between work and other activities in such a manner that the marginal value of time spent in each is equal, the value of time spent in all activities is equivalent to the average hourly contribution of labor to the national product.

To illustrate using 1980 preliminary national income and product accounts,[7] the gross national product in 1980 totaled $2,627.4 billion. Subtracting capital consumption allowances, indirect business taxes, rental income, net interest, corporate profits before taxes and reductions in

inventory yields the total contribution of labor to the national product, or approximately $1,343.6 billion. The total labor hours in 1980 is the product of the employed labor force (90,652,000), the average work week (35.3 hours) and the number of weeks per year, or 166.4 billion hours. The average hourly contribution of labor to the national product is found by dividing the total gross contribution of labor to the national product ($1,343.6 billion) by total labor hours (166.4 billion), or approximately $8.00 per hour.

The shortcomings of this approach are obvious. In reality, most individuals do not have unconstrained labor-leisure choices, basically because of institutional work hour standards. Additionally, labor's average product does not necessarily equal its marginal product. The approach undoubtedly understates the value of time of air travelers because their average hourly earnings are higher than that of the population as a whole. It is further deficient in that it does not account for the value of time of individuals whose productive activity is not measured in the national income and product accounts, e.g., retirees, housewives, students, children, etc.

FIGURE I

APPLIED VALUES OF TIME IN AIR TRAVEL

Study	Year	Value of Time in Business Travel	Value of Time in Nonbusiness Travel
Systems Analysis and Research Corporation	1964	1 x income	1 x income
Systems Analysis and Research Corporation	1966	Incremental percentage per work hour: 2.5 - 3.0 x earnings	"Not feasible"
McDonnell Aircraft Corporation	1966	1 x earnings rate	$1.00/hour
American Aviation	1966	2.5 x earnings	Not noted
Boeing-SST (FAA, 1967, Vol. II)	1966	1 x income	1 x income
Lockheed-SST (FAA, 1967, Vol. II)	1966	2 x earnings rate	1 x after-tax income
Institute for Defense Analysis-SST	1966	1 x earnings rate	1 x earnings rate
FAA-SST	1967	1.5 x earnings rate	1 x earnings rate
Boeing-V/STOL (Vol. II)	1967	1 x income	1 x income
Reuben Gronau Ph. D. dissertation	1967	.40-.45 x earnings rate	No "systematic relationship"
Charles River Associates-SST	1969	1.5 x earnings rate	1.5 x earnings
Reuben Gronau	1970	1.15-1.25 x earnings rate	No "systematic relationship"
Arthur DeVany	1971	1 x earnings rate	1 x earnings rate
Various FAA Facilities and Equipment Establishment Criteria and special analyses	1974 - 1980	1 x earnings rate	1 x earnings rate

2. Willingness-To-Pay Approach

Usually applied in attempts to measure the value of non-business or leisure travel, the willingness-to-pay approach can be direct or indirect in form. The direct willingness-to-pay approach involves direct inquiry of travelers' preferences and choices through the use of interviews or questionnaires, while the indirect willingness-to-pay approach deduces the value of time from observation of travelers' revealed preferences between alternative modes or routes of travel. Preferences shown by travelers in making choices between different combinations of travel time and cost provide a basis for inferring the trade-off between them -- the extra price that some travelers are willing to pay to avoid delay or to save travel time and the extra cost that some travelers are willing to avoid by spending more time in travel.

Because willingness-to-pay has the virtue of covering the value of time in travel for both purposes (value of productive time for business travelers and value of consumption time for nonbusiness travelers), a measure of willingness-to-pay provides a comprehensive measure of the value of time. To date, there has been little application of the direct willingness-to-pay approach to valuing the time of air travelers. This is presumably attributable to the inherent weaknesses of interviews and questionnaires. People may be unable to deal with the value of time in the abstract, resulting in responses which may be biased or different from what their actual behavior might be. The remainder of this discussion addresses typical applications of the indirect willingness-to-pay or revealed preference approach to valuing travel time.

One technique that has been used to measure the value of time in travel through observation of travelers' revealed preferences is based on the concept of elasticity of demand for travel. Elasticity of demand indicates the degree of responsiveness of the quantity demanded of a good or service to changes in the variable(s) influencing demand for that good or service. It depends upon percentage changes and is independent of the units used to measure quantity and the variable(s) influencing demand. This approach typically estimates the value of time in travel as the ratio of the elasticity of demand with respect to time to the elasticity of demand with respect to fare all divided by the ratio of time to fare, or

$$V_t = \frac{\dfrac{\text{Elasticity of demand with respect to time}}{\text{Elasticity of demand with respect to fare}}}{\dfrac{t}{f}} = \frac{\dfrac{\%\Delta D}{\%\Delta t}}{\dfrac{\%\Delta D}{\%\Delta f}} \times \frac{f}{t}$$

where,

V_t = the hourly value of time in travel
$\%\Delta D$ = percentage change in demand for travel
$\%\Delta t$ = percentage change in travel time
$\%\Delta f$ = percentage change in fare or price
f = fare or price
d = travel time (hours)

To illustrate, assume the air fare from Point A to Point B is $115.00, the average flight time from Point A to Point B is 4 hours, and elasticities of -.625 for time and -1.02 for fare.[8] These illustrative data imply a value of time in air travel of:

$$V_t = \frac{-.625}{-1.02} \quad x \quad \frac{\$115.00}{4} = \$17.62 \text{ per hour (illustration only)}$$

DeVany's[9] estimate of the value of time of air travelers based on derived elasticities of demand for air travel is a well known one. Based on actual fares paid for air travel between different city pairs and estimates of mean fare and time elasticities, DeVany estimated the value of time of air travelers in 1968 at $7.28 per hour. His estimates for coach and first class air travelers in 1969 from elasticity findings of Brown and Watkins[10] were $8.09 and $11.97 respectively. The similarity between his findings and the average wage rate of airline passengers prompted DeVany to suggest that "air travelers value their time at their wage." It is noted that adjustment of DeVany's values to 1980 dollars to account for inflation results in a value of time consistent with that which is later derived in this section.

DeVany's application of this approach has some major deficiencies. First, it is questionable if the structure of the determinants of cross-sectional travel between city-pairs is common to all city-pairs.[11] Second, as Gronau states, "the argument whether the price elasticity (in air transport) is less than or greater than unity goes back into the fifties and has not yet been resolved."[12] Third, it is questionable whether or not elasticities are constant over time. Fourth, as trip length increases fare elasticity increases and time elasticity decreases. DeVany's use of mean elasticities, therefore, gives cause to question his findings. To illustrate this latter point, Figure II presents fare and time elasticities at various trip lengths. Finally, in theory the approach requires the relative importance of all factors bearing on the demand for air travel. In addition to ignoring population and income, DeVany ignores other factors influencing the demand for air travel, such as convenience, comfort, safety, prestige of the mode of travel and other demand determinants.

Groneau,[13] relying on the works of Becker,[14] used data from a New York Port Authority survey conducted in April 1963 - March 1964 and estimated a series of regression equations with arbitrary values of time. He obtained estimates of both the price and income elasticities by selecting the value of time which yielded the highest explanatory power. For business travelers the highest explanatory power obtained was where the value of time was between 1 and 1.25 times average earnings. Unfortunately, for personal trips the highest explanatory power found was where the value of time equalled zero. Groneau argued that this may have resulted from the low degree of substitution of time between work and nonwork activities. Groneau's approach has two major shortcomings. First, it is questionable whether or not the regression coefficients are stable over time. Second, like DeVany, Groneau does not take into account the relative importance of many factors affecting the demand for air travel, such as convenience, comfort, safety, prestige of the mode of travel and other demand determinants.

FIGURE II

FARE AND TIME ELASTICITIES BY TRIP LENGTH[15]

Distance (Miles)	Fare Elasticity $\frac{\%\Delta D}{\%\Delta f}$	Time Elasticity $\frac{\%\Delta D}{\%\Delta t}$
100	- .722	-.768
400	- .944	-.596
1,001 - 1,500	-1.095	-.444
1,501 - 2,000	-1.115	-.425

D. The Issue of Multiple Valuation of Time in Travel

A number of values of travel time may exist. The value of travel time is likely to vary with the income of traveler, the purpose of travel, the time of day, the amount of time saved or delayed, the stage of travel where delay or time savings occur, etc. Although the concept is not new to the FAA, the Office of Management and Budget has suggested that FAA give consideration to establishing different values of time by traffic class (air carrier, air taxi, air commuter and general aviation).[16] Such disaggregation would account for the likelihood that the value of time varies with the passenger's income and to a limited extent the purpose of travel. As for the amount of time saved or delayed, the FAA recognizes the likelihood that the marginal value of time varies with the amount of time saved or delayed.

Unfortunately, there appears to be no sufficiently detailed empirical investigations of multiple time valuation which are suitable to practical and meaningful application by the FAA. Conceptual and informational deficiencies have hindered the few studies on the subject that have been attempted.[17] Travelers' characteristics relating to income, attitudes, and behavior patterns have not been observed or measured for all traffic classes. The average value of time is likely to vary not only between traffic classes but also within a class, regardless of whether calculated by income, earnings rate, utility or some other means. Meaningful improvement in precision would appear to require further disaggregation within each traffic class. Ideally, even time values for typical users of specific candidate investment sites and traffic routes/patterns should be developed. Given the state of the art of valuing time and available data, it appears impractical to differentiate values of time of air travelers at this juncture.

A consideration in the application of a monetary value to travel time is that travelers are not likely to perceive the cost of delay as a linear function. Below some measurable delay threshold, in the order of a minute to several minutes, travelers are probably insensitive and perhaps even unaware

of such delays. Given this consideration, it is sometimes argued that delays of such short duration have little or no value, and that it is unappropriate to value each minute of time below this threshold as 1/60 of the hourly value of time. This line of reasoning, which may be termed the "marginal approach," is not applicable, however, to systems analyses, such as in the case of FAA investment and regulatory decisionmaking processes. This exception may be readily understood by imagining a series of incremental and marginal efficiency improvements to air traffic control over time and assuming that each incremental improvement reduces delay by one minute. Applying the "marginal approach" to measure the cumulative monetary benefits would produce a value of zero, since each incremental improvement would have been valued at zero. Intuitively, however, the cumulative effect has a positive value. Application of a "systems analysis approach," on the other hand, would provide a defensible magnitude of value, since each incremental minute of improvement would have been valued at 1/60 of the hourly value of time.

E. Summary

Because the principal advantage of air travel is high speed, the value of time of air travelers can be of major importance in the economic evaluation of FAA investment and regulatory programs which bear on time spent in air travel.

A considerable amount of disparate work has been done both in the theory and the empirical measurement of the value of time. As the number of studies on the valuation of time has increased, the range of values has likewise increased. The diverse results of these studies suggests that valuation of time is still an uncertain exercise. The value of time is dependent upon a number of parameters which are specific to each individual's decision problem. Future research that explores the consumer's decision problem in detail will hopefully enhance the state-of-the-art of valuing time spent in travel.

The range of opinion on the value of time in air travel varies between some fraction of the earnings rate and three times the earnings rate. Obviously, this range makes the adoption of a value of time for FAA investment and regulatory decisionmaking purposes a rather tentative one. It is recommended that the hourly earnings rate of the "typical" air traveler be maintained as the norm or standard value of time in air travel until new approaches are successfully advanced or until new evidence suggests that a different basis is warranted. This recommendation is based on three major considerations. First, the value of leisure time and business time lost/gained should ideally be valued at their opportunity cost -- the pleasure or output which might have been realized/foregone if the delay/time savings had not occurred -- or at least equal to the wage level of the traveler involved. Second, the hourly earnings rate approximates the median of the range of "consensus" values found in the literature on the subject. And third, valuation of time in air travel at the earnings rate is in general accord with the findings of Groneau (1970)[18] and DeVany[19] whose works appear to be relatively systematic developments of the valuation of time in air travel, as attested by the extent to which their research and contributions are acknowledged and referenced in the literature on the subject.

The National Travel Survey,[20] a component of the Census of Transportation conducted by the Bureau of the Census, was relied upon to

approximate the annual income of the "typical" air traveler. The main objective of the National Travel Survey is to provide data, principally on a national basis, for use by federal and state agencies and other agencies and persons concerned with policy formation and promotional activities in the general field of travel. Past surveys profile the "typical" air traveler as a male professional or technical manager, approximately 41 years of age, on business travel by himself during the workweek and married with three dependents. Because the median income fell in the upper, open-ended class interval in the most recent survey (1972), the 1967 survey was used as a basis upon which to project the 1980 median income level of the typical air traveler. Inflating a 1967 median income of $14,052 using the Department of Labor Bureau of Labor Statistics Index of Adjusted Hourly Earnings (see the appendix to this report for inflator methodology), a value of approximately $35,200 is estimated as the annual income of the "typical" air traveler in 1980 dollars ((250.6/100.0) x $14,052). This estimate appears quite reasonable when compared to more recent, although unadaptable, surveys of airline travelers. An annual income of $35,200 equates to an average hourly earnings rate of $17.50, rounded to the nearest $.50 ($35,200 divided by 250 workdays per year divided by 8 hours per workday). $17.50, then, is the revised estimate of the value of time of air travelers in <u>1980 dollars</u>.

<u>Between interim revisions of this report, it is recommended that the value of time derived in this section be adjusted to future year dollars by the methodology outlined in the appendix to this report</u>.

SECTION II - VALUE OF A STATISTICAL LIFE

A. Introduction

In our society human life is valued higher than the mere product of a person over his lifetime. Life is felt to be precious and essentially invaluable. Nevertheless, economic decisions must be made continually, either explicitly or implicitly, between safety and the resources to be devoted to it. As applied to public policy decisionmaking, the value of a statistical life (as opposed to an identifiable life) is a basic tool used for measuring the benefits associated with investments and regulatory actions in such public programs as disease control, job safety, environmental standards, highway safety, accident control, etc. The use of an explicit value of a statistical life in public policy decisionmaking does not debase human life, but rather recognizes that resources are limited and that safety investments must be balanced with other demands for these resources. A variety of approaches to valuing life suggests values ranging from tens of thousands of dollars to several million dollars.

In the case of the FAA, the value of a statistical life is one of several economic determinants or "critical values" useful in the evaluation of programs which bear on aviation safety. This section outlines alternative approaches to valuing life and identifies that approach which is thought to provide the most comprehensive basis upon which to derive a revised estimate of its magnitude. Conceptually, the value of life derived here can be thought of as the minimum dollar sacrifice that society and users are or should be willing to make to decrease the probability of a statistical death to a level where one additional life is saved in the aviation system. The focus is on the "typical" air passenger: a 41 year old family member with an annual income in 1980 of $35,200 (see page 11).

B. Human Capital Approach

Probably the most common way of calculating the economic worth of a person's life, the human capital approach values life as the discounted present value of the expected lifetime earnings stream. Economists disagree, however, on the validity of valuing lives based on remaining lifetime earnings. Whereas some flatly oppose it as being meaningless, others argue that it is useful in establishing minimum values of the economic worth to society of saving or prolonging lives. An obvious problem of this approach is that it yields little or no value for the lives of retired persons, invalids, etc. A 1975 Social Security Administration estimate[21] of the average discounted future earnings of the entire population was $36,000, while that for a white male aged 25-29 was $230,000. Assuming real salary increases of 1.0% per annum for the next 25 years and a retirement age of around 65, the present value of the remaining lifetime earned income stream at the OMB-prescribed discount rate of 10 percent[22] for the "typical" air passenger (41 years old with an annual salary (from page 11) of $35,200 in 1980 dollars) is approximately $380,000.

C. Court Awards Approach

The court awards (for wrongful death) or judicial process approach customarily values human life as the sum of the present discounted value of the expected lifetime income stream plus compensation for pain and suffering. This approach is sometimes challenged on the grounds that it does not necessarily yield an equitable or economically sound value of life. That is, court awards may be based on the ability of the defendant to pay, may involve an element of retribution, and may be tempered by community judgment.

Two earlier efforts at establishing a value of an air passenger's life using this approach yielded values of $195,000 and $300,000 (1974 dollars). The FAA's Office of Aviation Policy and Plans used CAB data on non-Warsaw payments from 1966 to 1970 to project a value of $300,000 per fatality (1974 dollars). Noah, et al.,[23] surveyed court awards during the period 1971 through 1974 and established an average settlement of $195,000 per fatality (1974 dollars). In reconciling his findings with the value established by the FAA, Noah noted that average awards during the period 1971 through 1974 were significantly less than FAA's projections for these years. When awards for the period 1964 through 1967 were averaged into a singular value because of the relatively few number of settlements during these years and amended to the FAA trend line, a value of $195,000 was again established. Nevertheless, the FAA maintained the $300,000 value, presumably a compromise of values derived from court awards and values suggested by other approaches to valuing a statistical life.

Figure III outlines summary sample statistics of judicial awards in settlement of aviation fatalities during the 1970's, averaging $341,900 in constant 1980 dollars.

FIGURE III

SUMMARY SAMPLE STATISTICS OF JUDICIAL AWARDS IN SETTLEMENT OF NON-WARSAW AVIATION FATALITIES

		Average Settlement	
Year	Number of Settlements*	Current Year (000 Dollars)	Constant 1980 (000 Dollars)
1970	112	$165.3	$343.2
1971	170	123.7	239.9
1972	165	122.4	223.1
1973	99	148.2	254.4
1974	141	233.2	371.0
1975	29	205.8	302.3
1976	43	329.8	451.6
1977	8	250.0	318.3
1978	17	349.8	411.7
1979	10	461.5	503.3
Mean			341.9

*See Footnote 24

D. Willingness-to-Pay Approach

There has been an increasing trend to valuing life by reference to premiums individuals are willing to pay/accept to reduce/increase risk of death by a small finite amount. Two types or forms dominate these so-called "willingness-to-pay" approaches: one is based on replies to interviews or questionnaires which pose risky situations to the respondents (the direct approach); the other is based on observations of individuals' revealed preferences or behavior in production or consumption activity (the indirect approach). In both approaches an assessment is made of individuals' tradeoffs between income or wealth and exposure to risk of death. Empirical studies using willingness-to-pay approaches by Acton,[25] Brown,[26] Dillingham,[27] Howard,[28] Joksch,[29] Jones-Lee,[30] Schnelling,[31] Smith,[32] Thaler and Rosen,[33] Viscusi[34] and others suggest values of a life saved ranging from several thousand dollars to several million dollars.

The direct willingness-to-pay approach suffers from the shortcoming inherent with interviews and questionnaires in measuring what individuals say rather than how they might actually behave. The validity of this approach, therefore, depends on whether or not it can be expected to lead to responses which are biased relative to true preferences. The indirect willingness-to-pay or revealed preference approach sometimes is challenged on the grounds that many individuals may exhibit a low estimate of the probability of their demise and therefore a low estimate of the value of their lives.

The Transportation Systems Center of the U.S. Department of Transportation[35] used the indirect willingness-to-pay or revealed preference approach by drawing by analogy between airline travel risks and a study of job risks as conducted by Thaler and Rosen.[36] In addition to the risk premium revealed by a family on the value of the life of its breadwinner, TSC also attempted to account for other forms of active compensation to the family and passive losses absorbed by society as a consequence of the death. Because TSC's work is more akin to the value to self and others approach than the conventional willingness-to-pay approach, a further description of it is deferred to the following section.

E. Value to Self and Others Approach

In addition to losses to the individual, the value to self and others approach also takes into account the value of one's life to other persons and groups. This approach naturally follows the willingness-to-pay approach when the question arises as to whether the government (and others) should spend more to save an individual's life than the individual might be willing to spend to save his own life. Two past applications of this approach under the sponsorship of the FAA are considered noteworthy - a 1975 U.S. D.O.T. Transportation Systems Center (TSC) draft report entitled Economic Criteria for FAA Facility and Equipment Expenditures,[37] and a somewhat earlier although still relevant 1962 report by United Research, Inc., under the direction of Gary Fromm, entitled Economic Criteria for FAA Expenditures.[38] Since the logic common to these works form the framework within which the value of life developed later in this section is derived, relevant passages of each are reproduced below, and summarized in Figures IV and V, respectively. First, that of TSC:

"...the revealed preference approach (classified here as a value to self and others approach) allows one to infer the premium people place upon safety by observing their behavior. Thaler and Rosen[39] observed labor market behavior from this perspective. Essentially they measure(d)... differences in workers wages which are attributable to age, marital status, region of the country, broad occupational category, union status, race and several other factors and, notably, job risk. A multivariate regression analysis of 907 workers in 37 specific occupations (was) used to estimate the wage premium which people demand solely in order to persuade them to incur an additional risk of death.

There are several attractive features to this data. First, job risk and airplane risk are both comparable situations with respect to preferences. Each risk is assumed somewhat voluntarily, but the risk is not valued in itself. It is rather tolerated. (The value of a comparable reduction in the probability of death in an activity such as mountain climbing could be somewhat different. People engaged in this activity are likely to be risk-lovers. The labor market and aircraft occupants are probably comparable in their evaluations of the worth of measures designed to reduce risk.)

Second, this premium is expected to reflect a family valuation. That is, this premium is the amount needed to make the entire family indifferent between the additional exposure to that member and a smaller exposure with lower income. (This occurs because successive increments in job risk will be tolerated to the point where the last increment in risk is just equal to the additional compensation received. Thus people adjust their behavior so that their marginal subjective preferences are equal to objective market tradeoffs...) If all family members are valued equally, this statistic can apply to any one of them.

Third, it is probably not unreasonable to assume that the risks of death, permanent total disability, permanent partial disability, and temporary injury occur in the same relative proportions for job risk and aircraft occupancy. (The ratio of deaths to injuries in fact may be higher for aircraft occupants. If so, this will mean that the value of a reduction in death risk of .001 to a worker will exceed that to an aircraft occupant. For the worker's premium will then include some higher compensation for a higher risk of injury (at a constant level of risk of death in each activity.)) As such, the premium will reflect the compensation individuals require to be persuaded to face a combined risk of death and varying types of injury.

Two differences between aircraft occupants and workers in risky situations may mar the comparability of the valuations to some degree. Average aircraft occupants may well be willing to pay more to avoid a given risk than our sample of laborers. On the other hand, the fact that some of these people fly general aviation aircraft may suggest a smaller aversion to risk than...the sample of laborers. (Alternatively, general aviation flying may be explained not by risk loving, but by the time-saving, or pleasure it yields which is unrelated to the risk.) On balance it is hard to say. Average aircraft occupants are probably likely to pay somewhat more for a given risk reduction, which suggests Thaler and Rosen's estimates will be conservative.

However, the fact that entire families often fly on airplanes suggests that these risk premiums observed in the labor market will be too high. The compensation an entire family will require to undergo a joint risk to all of them should be less than four independent risks of equal magnitude to each of them separately. Put another way, the family is relatively less averse, in a certain sense, to situations where all may die jointly rather than individually.

In sum, these influences are likely to offset to some degree and make Thaler and Rosen's estimates of these risk premiums appropriate for subjective valuations of the worth of risk reductions in air traffic.

Thaler and Rosen's best guess as to the magnitude a family must receive each year to be compensated for an additional risk of death and related injury of .001 to one of their breadwinners is $176. For 1,000 workers, the amount is equal to $176,000. Since it is expected that one of these 1,000 will die during that year from work related risk, $176,000 is the value to the "engaged" individuals and their families of avoiding a statistical death and the associated level of statistical injury.

This estimate can be broken down as...

$$\$176{,}000 = V_1 + (P_2/P_1)\ V_2 + (P_3/P_1)\ V_3 + (P_4/P_1)\ V_4$$

where V_1, V_2, V_3, and V_4 are the total values to the families of the endangered workers of a reduction in one statistical death, one statistical permanent and total disability, one statistical permanent and partial disability, and one statistical temporary injury ... respectively and, P_2/P_1, P_3/P_1, and P_4/P_1 are the empirical ratios of permanent and total disabilities to deaths, permanent and partial disabilities to deaths, and temporary injuries to death, respectively for the sample of workers with which Thaler and Rosen deal.

The relevant magnitudes are V_1, V_2, V_3 and V_4. It is therefore necessary to make assumptions about the ratios of probabilities and those of values.

It can be assumed that the ratio of injuries of each type to deaths for this sample of workers is the same as it is for the population as a whole. Per thousand, 7.1 persons die each year.[40] The permanent and totally-disabled comprise 5.9 percent of our total adult population ages 18-65,[41] and the permanent and partially-disabled account for 11.3 percent. It is assumed that the disabled person lives an average of twenty-five years subsequent to his disability. Finally, it can be assumed that the ratio of temporary injuries to fatalities was 2 for Thaler and Rosen's sample. (While this number is purely arbitrary, we can be comforted by the fact that our results will be quite insensitive to its magnitude.)

Thus obtaining,

$$(P_2 / P_1) = (.059/25) / .0071 = .332$$
$$(P_3 / P_1) = (.113/25) / .0071 = .637$$
$$(P_4 / P_1) = 2$$

An attempt must be made to estimate the components (V_1, V_2, V_3, V_4) of the overall risk premium ($176,000). While the estimates here will be arbitrary, this will not matter as long as the relative proportions of deaths and injuries of each type are similar for Thaler and Rosen's sample and aircraft occupants.

Assume it is worth $x to someone and those close to him to experience a reduction in the risk of his death of .001 during this year. The question is what fractions of x he and his family would be willing to pay to reduce the risk of each type of injury to him by .001 during the next year. While death is final, some kinds of permanent and total disability may be equally unattractive _ex ante_ (e.g., complete paralysis) because of the feelings of guilt, burden, and uselessness they foster.

The actual fraction of $x is therefore likely to depend on what is meant by permanent and total disability. It will be assumed that the average member among those belonging to the 5.9 percent of the total adult population is not so seriously disabled that he and his family would have been indifferent between a .001 chance of death and a .001 chance of his current disability as viewed beforehand (an important qualifying assumption). Here it is assumed that if they would have been willing to pay $x to avoid a .001 chance of death, they would be willing to pay $x to avoid a .001 chance of a typical permanent and total disability.

Continuing this line of reasoning, a value of \$(.1x) and \$(.01x) to the ex ante worth of a reduction in the risk of permanent partial disability and temporary injury of .001 respectively is assigned. The equation can thus be rewritten, $\$176,000 = x + (.332)(.75x) + (.637)(.1x) + (2)(.01x)$ which is solved for $x = \$132,063$. Thus, $V_1 = \$132,063$, $V_2 = \$99,047$, $V_3 = \$13,206$, and $V_4 = \$1,321$. For now interest centers on V_1, but the latter statistics will be used later ... (in the next section of this report, Section III, Unit Costs of Statistical Aviation Injuries).

Thus far, only the compensation to engaged individuals and their families to make them indifferent between the risky and non-risky situation has been isolated. But they are making these choices, knowing that they are insured. That is, society will reimburse the survivors or the disabled through a combination of social and private insurance.

When some individuals in society are exposed to a greater risk of death, the rest of the households in that society are affected. This occurs because, on average, more deaths will result, and these deaths impose losses on the remaining survivors in the economy. Since these losses are small in relation to the remaining survivors' wealth, these losses to survivors can be evaluated at their actuarial levels.

The rest of society must compensate the family of the deceased in the form of private and social insurance. (This is not simply a redistribution of resources as Fromm whose work is reproduced later in this section). Society loses the resources the insurance payments would have purchased for them. Yet the family does not gain them. This is merely one component of the compensation which the family of the now deceased demanded in order to make it indifferent between the greater risks and more resources and smaller risk and less resources.) In 1973, the average amount of all private life insurance coverage for each insured family was \$28,800.[42] Since this amount applies to all family members, it is arbitrarily assumed that the aircraft occupant's coverage is two-thirds of this amount. (The aircraft occupant is more likely to be an earning member of the family and therefore more heavily insured.) Additional insurance administration costs are arbitrarily set at \$1,000. The costs of private insurance coverage for a statistical death to an average aircraft occupant are thus:

$$(\$28,800 + \$1,000) \times (2/3) = \$19,867$$

However, if this statistical death had not occured this year, it would have occurred perhaps twenty-five years

later. At this time society would have incurred the same real loss of resources. (Assuming insurance coverage does not change in real terms and also that the weighted average aircraft occupant's death would have occurred years later.) Deducting this loss of,

$$(\$19{,}867) \times (1/(1 + 1.10)^{25}) = \$1{,}834$$

yields a full cost of private insurance of $18,033 per statistical death to an average aircraft occupant.

By similar reasoning, society's losses through increased social insurance payments can be calculated. Considering only those who have been employed for five of the past ten years, survivors' coverage ranges from $305 per month to $550 per month depending upon the number of dependents. It is arbitrarily assumed than an average monthly payment of $427.50 which applies to two-thirds of the statistical deaths. It is further assumed that this payment lasts for nine years and that no payment would be made in the absence of the risk. (That is, it is assumed the statistical life saved would have lived to an age where survivor's insurance would no longer apply, that is, until either the dependents reached age 18 or until more than five years after the end of his working life.) (Again arbitrarily setting additional insurance administration costs at $1,000), the full cost of survivors' insurance can be calculated as

$$((\$427.50 \times 12 \times 5.759) + \$1{,}000) \times (2/3) = \$20{,}362$$

per statistical death to an aircraft occupant. The present value multiplier applied to a constant nine year earning stream discounted at 10 percent per year is 5.759.

The final component of active social compensation to the family of the deceased comes in the form of insured medical costs occurring prior to death. Here calculations[43] can be borrowed from an earlier analysis and medical costs inflated to apply in early 1975. Insured medical costs per statistical aircraft occupant fatality turn out to be $1,337.

There remains the issue of passive losses suffered by society. (Again, these are not simply redistributions of resources or transfer payments, as Fromm's work discussed later in this section classifies them. Society loses the resources or utility the transfers would have purchased or accrued to them.) When a working member of society dies, the rest of society loses the discounted value of the total non-property taxes from his labor effort less the cost of government services he consumes for the balance of his working life. If one assumes a net loss of salary income of $15,000 to the family, and

approximates the ratio of taxes to income by one-quarter,[44] the present value of the net tax loss can be calculated as

($15,000) x (1/4) x (8.514) = $31,928 per statistical death.

The present value multiplier of a constant 20-year stream of tax losses, discounted at the rate of 10 percent is 8.514.

Should this statistical death result, society will likely forego some net contributions amount(ing) to an average of 2 percent of gross income. A yearly loss of $15,000 in gross income per statistical death will result in a yearly reduction in charitable contributions of $300. If a similar value of $300 per year to the community for services rendered by the deceased is assumed, the total twenty year loss of charitable giving amounts to $600 x (8.514) = $5,108. (These contributions are net since premature death will result in an earlier disposition of the charitable portion of one's estate. This we ignore.)

Finally, there are the losses to the employer in the form of retraining costs. Most "training" costs have been incurred privately by the employee; on the job training costs are likely to be rather small except for certain occupations and many of these will have already been recouped by the employer. Furthermore, turnover in jobs is, and probably should be, fairly great anyway. Thus, their value is set at $1,000 per statistical death...

The costs calculated above assume a forty-year old family member whose family earns $15,000 more as a result of that person's presence than it ordinarily would...(Summarizing in Figure IV and) rounding to thousands to avoid any pretext at unnecessary precision... the social worth of preventing one statistical aircraft occupant's death appears to be in the general neighborhood of $210,000 (mixed-year dollars)."[45]

FIGURE IV

SUMMARY OF TSC'S APPLICATION OF THE
"VALUE TO SELF AND OTHERS" APPROACH TO VALUATION OF A STATISTICAL LIFE
(Mixed-Year Dollars)*

Cost Element		Loss
Active Compensation to Family:		
Risk premium (V_1)	$ 132,063	
Private insurance	18,033	
Social insurance	20,362	
Health insurance	1,337	$171,795
Passive Loss Absorbed by Society:		
Lost Taxes	31,928	
Lost Charity/Community Services	5,108	
Employer Losses	1,000	38,036
Total Loss		$209,831

*Risk premium is in terms of 1967 dollars, while all others are in terms of 1973 dollars. Adjustment of the former to 1973 dollars yields $192,812, or a total loss of $270,580 in 1973 dollars.

Another application of the value to self and others approach was performed in 1962 by United Research, Inc., under the direction of Gary Fromm.[46] Relevant passages of his report are reproduced below:

> "...This discussion will proceed by considering the value of the individual's life to those persons or groups affected by his death. Computations are based on 1960 dollars...
>
> The Individual Himself: The value of an individual's life to himself is basically a noneconomic one and depends to a large extent on his personal view of himself and on whatever underlying philosophical orientation is presupposed. (It should be noted here that the value an individual might place on his life under particular circumstances--such as that involved in the contemplation of suicide--may not be equal to an objective valuation of his life.) In crude terms, the value of life for the individual concerned can be expressed as the net satisfactions, economic and noneconomic, that he would have realized had he lived his normal term.

Although a person's satisfactions from life are extremely individualistic, as a minimum amount we might assign to them the present value of his earning stream. For persons involved in fatal airplane accidents, this amounts to an average of $210,000. (The present value of the individual's earning stream is computed by assuming an average (mean) salary of $13,000, a yearly increase of 2-1/2% in salary, assets of $25,000, 40 as the average at death (a lower age would raise expected lifetime earnings and the present value), and taking a discount rate of 6%. These figures are all on the basis of 1960 dollars. They are URI estimates; in the case of "average salary" and "average age at death," they are based on the Fortune Magazine air travel survey and studies conducted for the Travel Research Association and Port of New York Authority. Calculations are made on a pretax basis since it is assumed that benefits equivalent to the amounts paid are derived from the disposition of tax money. Of this amount, $185,000 also represents the loss to the economy in the form of decreased output. The assumption is made that individuals are paid their marginal products (if they are exploited, the loss to the economy is even greater), but it is not necessary to assume that there is full employment since the incremental losses in efficiency at each stage after the chain of substitution of personnel has taken place would probably approximate the passenger's salary.) The present value of the individual's total income, rather than only that segment directed toward his personal consumption, is used in this calculation since the individual derives satisfactions from all uses made of his income. For example, the individual is presumed to allocate his income between personal and family uses in that manner which best enhances his net satisfactions.

The Individual's Family: The individual's family suffers both a noneconomic and an economic loss. The family loses the net value of such things as the love, companionship, direction, and support which the passenger would have provided had he lived, and the satisfactions derived from their sharing his pleasures with him.

In the case of the death of an earning member of the family, the family also loses the discounted value of the family's consumption stream that would have been derived from the member's earned income and its prorated share of the member's contribution toward the family's increase in asset position. (This is an element similar to, but separate from, the satisfactions an individual derives from that part of his income devoted to his family.) It is reasonable to estimate that approximately two-thirds of the average earned income of individuals killed in airplane accidents is devoted to the consumption of other family members and toward increasing their prorated share

of total family assets. The individual's family, therefore, suffers a loss of $123,000. To this should be added the economic costs concerned with burial, mourning, and other last rites, reduced by the present value of such expenses had the individual lived his normal term.

It should be noted here that any amounts that the family may receive in insurance payments...do not enter into the calculations since these are transfer payments and so do not have a positive net over-all economic effect (the gains of the beneficiary are the losses of the insurance company and its stockholders and clients) in the calculation of the value of a human life lost in an airplane accident.

The Individual's Friends and Community: The individual's friends and his community lose the net noneconomic satisfactions that they would have derived from the individual had he lived. They also suffer an economic loss equal to the net value of the noncompensated services the individual would have rendered to them. (The magnitude of this loss is especially apparent in the case of a man who renders such significant community service as that connected with heading up a Community Chest drive.) Assuming that the average individual contributes an amount equal to approximately 15% of his working time to noncompensated services for friends and community, the present value of this economic loss amounts to $28,000.

The Individual's Employer: At a minimum, the individual's employer loses the economic costs of restaffing to fill the dead passenger's position compared with what the situation wuld have been under conditions of normal turnover. On an average, such costs might approximate one-third of the yearly income of individuals lost in airplane accidents, or approximately $4,000.

The employer might also suffer a further economic loss if the individual had certain unique characteristics so that the employer could not secure an equivalent replacement for him.

The Economy as a Whole: To the extent that the occurrence of airplane accidents resulting in fatalities influences a percentage of the traveling public to forego what otherwise would have been economically valuable trips or to travel by less efficient modes, the economy as a whole suffers a net economic loss. It is not possible to calculate this amount.

Furthermore, insofar as the average individual killed in an airplane accident is paid less than is economically merited (in economic terms: less than his marginal

product), the economy suffers a further loss from his death.

The Government: The FAA and the CAB incur costs directly concerned with accident investigation. (The governmental role of investigating aviation accidents now rests with the NTSB and the FAA.) An approximate figure for the cost of this activity per fatality is arrived at by imputing the expenses of accident investigation, allocating a proportion of these expenses toward the examination of fatalities as opposed to injuries, and dividing this figure by the annual number of fatalities. The total cost per fatality of FAA and CAB investigation approximated $4,000 in 1960. (Costs involved in preventing accidents are not included in this computation because these should not be ascribed to fatalities which have occurred but to those potential fatalities which it is assumed have been prevented by such action.)

The government also incurs economic and noneconomic losses due to the decline in prestige resulting from having an air transportation system in which there has been loss of human life.

Air Carriers: Airlines incur a direct economic cost for accident investigation and other related costs which can be estimated at $4,000 per fatality. (Money paid in settlement of claims is a transfer payment and so is not included here.)

Owing to the occurrence of air accidents, individuals shift from air to other forms of transportation. Assuming this results in the average load factor on all transportation facilities being lower than it would have been, there is a net economic loss to transportation agencies, since greater over-all investment is required for the same number of revenue passenger-miles...

In conclusion, then, the minimum economic cost per fatality in 1960 amounted to $373,000 (as summarized in Figure V). (This figure is the sum of the economic value of the individual's life to himself, $210,000; the economic loss to his family, $123,000; to his friends and community, $28,000; to his employer, $4,000; to the government, $4,000; and to airlines, $4,000. It does not include the losses the airlines sustain from the decrease in passenger-mile levels which result from fatalities.) There are also other economic losses incurred from passenger fatalities for which it is not possible to assign a specific value. Furthermore, this sum does not include a number of noneconomic values which can not be directly translated into economic terms but which have great importance in our society. The figure of $373,000

then should be looked upon only as a floor in calculating the value of a human life lost in a 1960 air carrier accident...

...The analyses of the value of human life lost...in general aviation accidents is the same as for air carriers, with the exception that the average income of the individual involved is higher. The 1960 income of business general aviation passengers (is)...estimated at $20,000. For personal flying a lower figure, $13,000, has been selected as representative of pilot or passenger income (this corresponds to the average income of passengers on air carrier flights).

Data on the incomes of professional business general aviation pilots...and assumptions (based on these statistics) about the incomes of persons engaged in commercial and instructional general aviation activities led...to an estimate of an average 1960 income of $12,000 for these individuals. Weighting the above incomes by flying hours in each class resulted in an average 1960 income of $15,000 for persons utilizing general aviation.

Therefore, the losses resulting from fatalities in general aviation in 1960 (as summarized in Figure V) were estimated to be: for the individual, $242,000; for his family, $142,000; to the community $32,000; and to his employer, $4,500. Government accident investigation costs were assumed to be $1,500 per fatality. (Government accident investigation costs were derived by dividing the sum of CAB expenditures for the Bureau of Safety plus twice that amount for FAA accident outlays, by the total number of air carrier and general aviation fatalities and serious injuries. Air carrier fatalities and injuries were accorded twice the weight of those in general aviation because of the greater complexity of aircraft accidents, and causal determinations in the airline field. This method of allocation, of course, provides no funds for the investigation of incidents involving minor or no injury to passengers and little or no damage to aircraft. However, since the total cost of analyses in this area is probably low, the error introduced by distributing the money for these investigations to fatal accident examinations is minimal.) Thus, the total loss per fatal injury equalled $422,000."[47]

FIGURE V

SUMMARY OF FROMM'S APPLICATION OF THE "VALUE TO SELF AND OTHERS" APPROACH TO VALUATION OF A STATISTICAL LIFE (1960 Dollars)

COST ELEMENT	AIR CARRIER OCCUPANT	GENERAL AVIATION OCCUPANT
Direct Costs:		
Employer	$ 4,000	$ 4,500
Government Accident Investigation	4,000	1,500
Airline Accident Investigation	4,000	N/A
Indirect Costs:		
Passenger	210,000	242,000
Family	123,000	142,000
Community Services	28,000	32,000
	$373,000	$422,000

F. Summary

The somewhat subjective and conceptual construct of the value of a statistical life is a basic tool of economists, program planners and others interested in measuring the social benefits associated with investments and regulatory actions in public programs. Although life is felt to be precious and essentially invaluable, economic decisions must be made continually, either explicitly or implicitly, between safety and other competing demands for limited resources. In the case of the FAA, the value of a statistical life is one of several economic determinants or "critical values" useful in the evaluation of programs which bear on aviation safety.

It is the role of government to maximize the welfare of its constituents. "Welfare" includes not only material factors but also noneconomic satisfactions, such as utility and joy of life, that an individual may realize through a normal term of life. Ideally then, a value of life for government decisionmaking purposes should account for both economic and noneconomic factors. Unfortunately, and as might be expected, none of the approaches to the valuation of human life fully satisfies this ideal. Literature on the value of life suggests values ranging from tens of thousands of dollars to several million dollars.

An acceptable solution to this dilemma is to rely upon that approach that comes closest to providing the most comprehensive valuation. The value to self and others approach and indirect willingness to pay approaches appear to best satisfy this criterion. The human capital approach is deficient in that it addresses only the discounted lifetime income stream and fails to account for the effect of one's death on other parties. It further fails to give

value to nonmarket activity. The court awards approach, by definition, is based on the judicial process which may or may not provide an equitable or economically sound value of life, i.e., court awards may be based on the ability of the defendant to pay, may involve an element of retribution, and may be tempered by community judgment. Lastly, the direct willingness-to-pay approaches have not been refined or tested to the extent necessary to place reliance on them at this juncture.

Given this premise, Figure VI derives a revised estimate of $530,000 in 1980 dollars as the value of a statistical air traveler's life. It is based on a value to self and others approach and incorporates an indirect willingness-to-pay or revealed preference approach as a measure of the value of life to the individual. This derivation is an update, with modifications, of the application employed by T.S.C., as reproduced earlier in this section. Conceptually, this value can be thought of as the minimum dollar sacrifice that society and users are or should be willing to make to decrease the probability of a statistical death in the aviation system. It is noted that this value approximates the average 1979 judicial settlement of $503,300, after making an allowance for inflation, and represents a compromising median of the range of values suggested by the literature on the subject.

Because the value of life involves economic aspects, some of which are difficult to reasonably quantify, and non-economic aspects, which cannot be reasonably quantified, the value derived here is useful in setting a floor but in no sense a ceiling to the value of a statistical life. Other costs attributable to the loss of life in the aviation system not imputed in this valuation include but are not limited to the following: loss to family and friends of the value of such things as love, companionship, direction, etc.; economic cost to the employer where the deceased possessed unique talents or characteristics which cannot be replaced; economic costs of burial, mourning and other last rites reduced by the present value of such expenses had the individual lived a normal term of life; economic cost of the extent to which aviation fatalities influence a portion of the traveling public to forego what otherwise would be economically valuable trips or to travel by less efficient modes; decline in prestige of the Government resulting from managing an air transportation system in which there has been loss of life; etc.

Between interim revisions of this report, it is recommended that the value of life derived in this section be adjusted to future year dollars by the methodology outlined in the appendix to this report.

FIGURE VI

VALUE OF A STATISTICAL AIR TRAVELER'S LIFE
(1980 Dollars)

COST ELEMENT	NATURE AND BASIS OF COST	COST
Active Compensation to Family		
Risk Premium	Estimated compensation, before insurance, demanded by air travelers to assume an additional risk of death by a small finite amount. Based on analogy with study by TSC[48] which relied on the findings of Thaler and Rosen.[49] Adjusted from 1967 dollars to 1980 dollars by the Department of Labor Bureau of Labor Statistics Index of Adjusted Hourly Earnings ($132,063 x(250.6/100.0)).	$330,950
Private Insurance	Estimated private life insurance coverage of the typical aircraft occupant, reduced by coverage if the individual had lived an additional 30 years. Assumes the average coverage for each insured family is $47,000[50] of which 2/3 is allocable to the aircraft occupant, and insurance administration costs of $1,500 and a ten percent discount rate: ($47,000 + $1,500) x (2/3) = $32,333; $32,333 x $(1/(1+.10)^{30})$ = $1,853; $32,333 - $1,853 = $30,480.	30,480
Social Insurance	Present discounted value (@ 10%) of increased social insurance payments over a nine year period. Assumes the "typical" air traveler has three dependents and average covered earnings under social security. ((($820.00 per month x 12 x 5.759) + $1,000) x 2/3).	38,446
Health Insurance	Estimated insured medical costs occurring prior to death. Based on 1972 medical costs per motor vehicle fatality of $1,125,[51] adjusted to 1980 dollars by the Consumer Price Index for Medical Care ($1,125 x (265.7/132.5)).	2,256
Passive Losses Absorbed by Society	These are not simply redistributions of resources as classified under Fromm's approach. Society loses the resources or utility these transfers would have purchased or accrued to them. Yet the family does not gain them. This reasoning also applies to the above forms of insurance compensation, components of the total compensation which the family of the now deceased demanded in order to make it indifferent between greater risks and more resources and smaller risk and less resources.	

Lost Taxes	Present discounted value (@ 10%) of the "typical" air traveler's non-property taxes over 25 years, less the cost of consumed government services. Assumes an annual earned income of $35,200 (see page 11) and a ratio of taxes to gross income of 1 to 3.4 ($35,200 x (1/3.4) x 9.077).	93,974
Lost Charity	Present discounted value (@ 10%) of the "typical" air traveler's contribution stream of charitable contributions and community services over 25 years. It is assumed that the value of contributed time is equal to the earnings rate. Estimated at 5% of the annual income of the "typical" air traveler (see page 11) ($35,200 x .05 x 9.077).	15,976
Employer	Losses to the employer in the form of retraining and restaffing costs. Whereas Fromm's[52] allowance for such costs appear to be high (one third of employees annual income), those of TSC[53] appear to be low (approximately 7% of the employee's annual income). The mean of this range, as applied to the "typical" air traveler's annual income (see page 11), is applied here (.20 x $35,200).	7,040
Accident Investigation Costs	Estimated accident investigation costs incurred by government (NTSB and FAA) and private parties (air carriers, manufacturers, etc.). Based on accident investigation costs per fatality in 1978, adjusted to 1980 dollars.[54]	10,000
Total		$529,122 or $530,000

SECTION III - UNIT COSTS OF STATISTICAL AVIATION INJURIES

A. Introduction

As with the value of a statistical life discussed in the preceding section of this report, the unit costs of statistical aviation injuries are ones of several economic determinants or "critical values" useful in evaluating FAA investment and regulatory programs which bear on aviation safety. Because of the lack of information about the extent of aviation injuries and the length of hospitalization and medical costs resulting from them, it is difficult to assign unit costs to statistical aviation injuries to which a high level of confidence may be attached. Be that as it is, this section outlines alternative approaches to valuing statistical aviation injuries and identifies that approach which is thought to provide the most comprehensive basis upon which to derive revised estimates of their magnitude.

B. Court Awards Approach

The court awards or judicial process approach to valuing the costs of injuries in aviation accidents is based on jury verdicts and settlements awarded to survivors. As with its application to valuing a statistical life, the court awards or judicial process approach to valuing statistical aviation injuries may or may not be equitable or economically sound (e.g., awards may be based on the defendant's ability to pay, may involve an element of retribution against the defendent and may be tempered by community judgment).

Figures VII, VIII, and IX outline summary statistics and frequency distributions of a nonscientifically-selected sample of 145 non-Warsaw settlements in mixed-year dollars to persons receiving non-fatal injuries in aviation accidents occurring between 1976 and 1980.[55] Because of the nonscientific nature of the sample, caution should be exercised in drawing unqualified inferences from these data. These data are presented here only for completeness of presentation and for comparison with other approaches to valuing statistical injuries discussed later in this section.

C. Willingness-to-Pay Approach

As with its application to valuing a statistical life, the willingness-to-pay approach to valuing statistical aviation injuries can be direct or indirect in form. In either case an assessment is made of individuals' tradeoffs between income or wealth and exposure to injury, providing a basis upon which to value injuries. The direct approach relies on the use of questionnaires and interviews, while the indirect approach is based on observations of preferences revealed by individuals in making decisions that bear on their exposure to risk of injury.

The direct willingness-to-pay approach suffers from the shortcoming inherent with interviews and questionnaires in measuring what individuals say rather than how they would actually behave. The validity of this approach, therefore, depends on whether or not it can be expected to lead to responses which are biased relative to true preferences. The indirect willingness-to-pay

FIGURE VII

SUMMARY STATISTICS OF A (NONSCIENTIFICALLY-SELECTED) SAMPLE OF SETTLEMENTS FOR INJURIES INCURRED IN NON-WARSAW AVIATION ACCIDENTS BETWEEN 1976 AND 1980[56]
(Mixed-Year Dollars)

	Size	Range	Mean	Median	Standard Deviation
Sample	145	\$0-\$3,027,500	\$ 53,689	\$ 2,500	\$274,162
Sample Subset* ("Minor" injuries less than \$20,000)	119	\$0 to \$18,764	\$ 3,389	\$ 1,803	\$ 4,154
Sample Subset* ("Serious" injuries \$20,000 or more)	26	\$ 22,618-\$3,027,500	\$283,905	\$104,000	\$604,736

* The classification of "minor injuries" as those resulting in settlements of less than \$20,000 and "serious injuries" as those resulting in settlements of \$20,000 or more is arbitrary. This arbitrary division is used only for illustration of this sample.

approach can be challenged on the grounds that many individuals may exhibit a low estimate of the probability of injury and therefore a low estimate of their willingness-to-pay to avoid it.

D. Value to Self and Others Approach

The value to self and others approach to valuing statistical aviation injuries is akin to its application to valuing a statistical life. As with the basis adopted to derive a revised estimate of the value of a statistical life, the works of the U.S. D.O.T. Transportation Systems Center[57] and Fromm[58] form the framework within which revised estimates of the unit costs of statistical aviation injuries are derived in this section. Again, the relevant passages of each are reproduced below and summarized in Figures X and XI, respectively. Both are continuations of the extracts presented in the preceding section of this report on the value of a statistical life. First, that of TSC:

> "...The conceptual categories of loss associated with statistical injuries are identical to those associated with a statistical death. The risk premium needed to induce a group of people to assume an overall risk equivalent to one statistical injury of each of the various kinds (V_2, V_3, and V_4) has already been estimated. Therefore, the average compensation under social insurance for various types of disability will now be considered.

FIGURE VIII

FREQUENCY DISTRIBUTION OF (NONSCIENTIFIC) SAMPLE OF SETTLEMENTS FOR "MINOR" INJURIES 59
INCURRED IN NON-WARSAW AVIATION ACCIDENTS
(1976-1980)

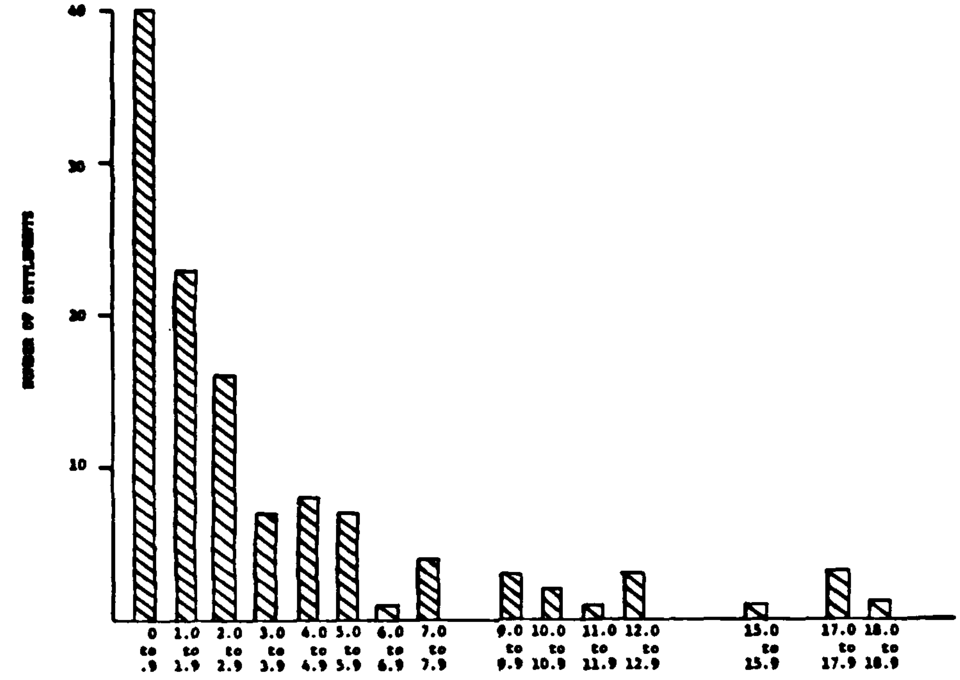
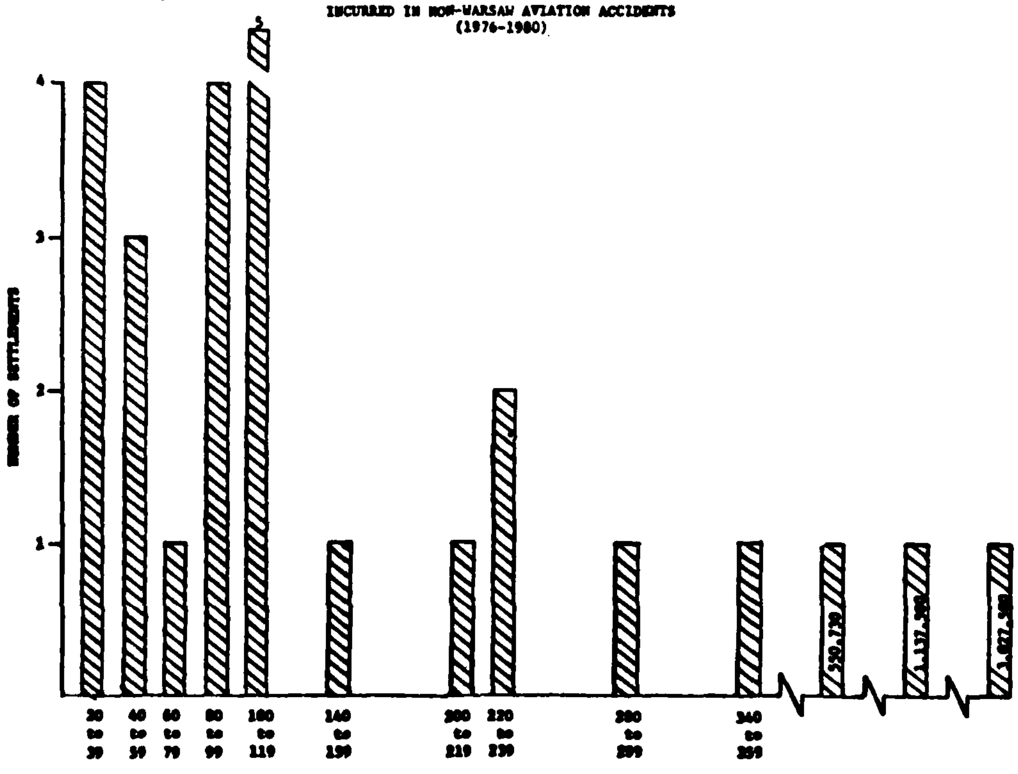


FIGURE IX

FREQUENCY DISTRIBUTION OF (NONSCIENTIFIC) SAMPLE OF SETTLEMENTS FOR "SERIOUS" INJURIES 60
INCURRED IN NON-WARSAW AVIATION ACCIDENTS
(1976-1980)



To qualify for disability benefits under the Social Security Administration, a forty-year old individual must a) prove his disability will last at least one year and b) have worked at least five of the past ten years. (Since disability coverage is ignored under supplemental security income and state programs, liberal assumptions are made about disability coverage under the Social Security Administration.) His coverage will then range anywhere from $93.80 to $640.00 depending upon the number of dependents and the amount of past years' contributions. Here it is assumed that the individual is covered for thirty years at the average of the maximum and minimum coverage, that is, at $366.90 per month. The present value of social insurance is then

$$((366.90) \times (12) \times (9.863)) + \$1,000 = \$44,425$$

where 9.863 is the present value multiplier for a constant monthly stream of benefits discounted at .10. Direct data on the present value of total disability coverage held with private insurance companies could not be located. However, one can solve for this amount using several plausible assumptions and related data.

Consider a population of N individuals, where the i^{th} individual has total private life insurance coverage C_f^i and total private disability coverage C_d^i. Let the probability of a fatality (disability) to the i^{th} individual during a year be q_f^i (q_d^i). Let P_f (P_d) be total life (disability) insurance payments during a particular year. If it is assumed that all payments are made in a lump sum, then

$$\sum_{i=1}^{N} q_f^i C_f^i = P_f \qquad \sum_{i=1}^{N} q_d^i C_d^i = P_d$$

These two equations merely state that an insurance company's payments in any particular year will be equal to their actuarial liabilities.

If the various probabilities of fatality and disability are statistically independent of the amount of individual coverage, one can rewrite these equations as,

$$\sum_{i=1}^{N} E\left(q_f^i\right) E\left(C_f^i\right) = P_f \qquad \sum_{i=1}^{N} E\left(q_d^i\right) E\left(C_d^i\right) = P_d$$

interpreting $E(q_f^i)$ to be the average individual probability of death and $E(C_f^i)$ to be the average individual coverage. The notation can be simplified and

these written as $\bar{q}_f$ and $\bar{C}_f$ respectively. Using a similar simplification for disability coverage, these two equations can be rewritten,

$$N\,\bar{q}_f\,\bar{C}_f = P_f \quad ; \quad N\,\bar{q}_d\,\bar{C}_d = P_D$$

Since our interest centers on C_d these two equations can be combined to write:

$$C_d = \frac{P_d}{P_f}\,\frac{\bar{q}_f}{\bar{q}_d}\,\bar{C}_f$$

The expression (P_d / P_f) is calculated from two years of data[61] to be .035, assuming that two-thirds of these payments go to the permanent and totally disabled and one third to the permanent and partially disabled. Their fractions are thus .023 and .012 respectively.

The ratio of $\bar{q}_f$ to $\bar{q}_d$ for various types of disability has already been estimated (the inverse of these ratios for permanent and total disability, permanent and partial disability, and temporary disability derived to estimate V_1, V_2, V_3 and V_4) and is 3.01 for permanent and total disabilities and 1.57 for permanent and partial disabilities. $\bar{C}_f$ was also calculated... to be (\$28,800 + \$1,000) x (2/3) = \$19,867 when insurance administration costs are included. Estimated private coverage costs $\bar{C}_d$ for permanent total disability and permanent partial disability are therefore \$1,375 and \$374 respectively.

The medical costs associated with the three types of injury are included as the last component of active social compensation to the endangered individual's family. Their inclusion assumes complete insurance coverage, borrowing the results of an earlier study with appropriate adjustment for inflation in medical costs. They are \$9,282, \$3,332, and \$375 for the three types of injury.

Assumptions about the passively-absorbed societal losses are somewhat arbitrary. It is assumed the losses for permanent total disability, permanent partial disability, and temporary disability are 100, 50 and 0 percent of those for a fatality..."[62]

Other applications of the value to self and others approach to valuing statistical aviation injuries were performed in 1962 and 1968 by Fromm of United Research, Inc.[63] Relevant passages of his 1962 report are reproduced below:

"...The analysis for the determination of serious injury costs is similar to that for loss of life. The individual is unable to work and earn his salary and, in addition, must pay medical expenses. His family loses their share of the income too. (Again ...any insurance or other compensation for the accident is irrelevant, since it represents a transfer of assets and the gains of the passenger and his family from this source is matched

FIGURE X

SUMMARY OF T.S.C.'S APPLICATION OF THE "VALUE TO SELF AND OTHERS" APPROACH TO VALUATION OF UNIT COSTS OF STATISTICAL AVIATION INJURIES
(Mixed Year Dollars)*

Cost Element	Loss: Permanent Total Disability	Loss: Permanent Partial Disability	Loss: Temporary Injury
Active Compensation to Family:			
Risk premium (V_2, V_3, V_4)	$ 99,047	$13,206*	$1,321*
Private Insurance	44,425	44,425	0
Social Insurance	1,375	374	0
Health Insurance	9,282	3,332	375
	$154,129	$61,337	$1,696
Passive Losses Absorbed by Society:			
Lost Taxes	$ 31,928	$15,964	$ 0
Lost Charity/Community Services	5,108	2,554	0
Employer Losses	1,000	500	0
	$ 38,036	$19,018	$ 0
Total Losses	$192,165	$80,355	$1,696

*Risk premiums are in terms of 1967 dollars, while all others are in terms of 1973 dollars. Adjustment of the risk premiums to 1973 dollars yields values of $144,609, $19,281 and $1,929, or total losses of $237,727, $86,430 and $2,304 in 1973 dollars.

by the losses of others.) There are accident investigation costs to be borne by government agencies and the airlines, and the community loses the services of the passenger for a period of time.

It has been assumed that, on the average, this interval is one year (as indicated below, Fromm later revised this to 6 months). That is, the injured passenger requires a

year to recuperate completely from the accident. (Because of lack of information on the extent of injuries, it is assumed that the recovery is complete and not marred by life-long physical or economic impairment of the individual's physical functions or earning power. If these occur, however, they should be taken into account by raising the loss in the expected earnings stream and including a satisfactions diminution allowance for the handicap.) Thus per serious injury in 1960, the passenger's loss was $13,000, the family lost satisfactions worth $8,700, and the community was denied services valued at $3,800. Airlines and government agencies, on an average basis, are assumed to spend as much for the investigation of serious injury accidents as for fatalities (this is logical since both are frequently found in the same accident), $4,000 per person for each group. The remaining cost is for medical expenses which are estimated to total an average of $50 per day for one year, or $18,250. No provision has been made for any employer costs due to the loss of an employee for one year. It is presumed that responsibilities, such as management, sales, etc., will temporarily be realigned to accommodate the individual's absence. This would result in some additional charges.

Taking all the above costs into account, the estimated total cost per serious aviation injury in 1960 was $51,750. This, of course, does not include any allowance for the suffering endured by the injured passenger, which, if it were added, would substantially raise the figure shown. No estimate was prepared for the cost of minor injuries because their extent is unknown, many result from nearly uncontrollable causes (e.g., turbulence) and the total value involved is probably negligible...

The analysis of the value of injuries suffered in general aviation accidents is the same as for air carriers, with the exception that the average income of the individual involved is higher (and airline accident investigation is not relevant)... Application of the techniques employed to evaluate the losses arising from serious injury in air carrier accidents leads to an estimated cost of $49,150 per general aviation serious injury in 1960. This figure is composed of $25,000 to the individual and his family, $18,250 in medical expenses, $4,400 in community seryices and $1,500 for government accident investigation. Again, as above, no permanent handicap is assumed..."[64]

In a later study,[65] Fromm revised some of his earlier estimates. In addition to revising his estimate of the period of recuperation for a serious injury from one year to six months, he also estimated the costs of minor injuries, assuming a one month recuperation period. Figure XI summarizes

Fromm's later estimates of the costs of serious and minor injuries in terms of 1960 dollars.

E. Summary

As with the case of valuing human life discussed in the preceding section of this report, the costs of unit statistical injuries are ones of several economic determinants or "critical values" useful in the evaluation of investment and regulatory programs which bear on aviation safety. Again, the value to self and others approach appears to provide the most comprehensive valuation. Given this premise, Figure XII derives revised estimates of the costs of unit statistical serious and minor injuries, $38,000 and $15,000 respectively, in terms of 1980 dollars (rounded to nearest $1,000 to avoid specious accuracy). Conceptually, these values can be thought of as the minimum dollar sacrifice that society and users are or should be willing to make to decrease the probability of the respective types of injury in the aviation system.

FIGURE XI

SUMMARY OF FROMM'S APPLICATION OF THE "VALUE TO SELF AND OTHERS" APPROACH TO VALUATION OF UNIT COSTS OF STATISTICAL AVIATION INJURIES
(1960 Dollars)

	Serious Injury		Minor Injury	
Cost Element	Air Carrier Occupant	General Aviation Occupant	Air Carrier Occupant	General Aviation Occupant
Direct Costs				
Medical Expense	$ 9,125	$ 9,125	$ 1,520	$ 1,520
Government Accident Investigation	4,000	1,500	4,000	1,500
Airline Accident Investigation	4,000	N/A	4,000	N/A
	$17,125	$10,625	$ 9,520	$ 3,020
Indirect Costs				
Passenger	$ 6,500	$ 7,500	$ 1,080	$ 1,250
Family	4,350	5,000	725	830
Community Services	1,900	2,200	320	370
	$12,750	$14,700	$ 2,125	$ 2,450
Total Cost Per Injury	$29,875	$25,325	$11,645	$ 5,470

These derivations incorporate the logic common to the works of the U.S. D.O.T. Transportation Systems Center and Fromm discussed earlier in this section. Whereas the logic adopted in this report for the value of life follows more closely that of T.S.C., the logic followed for the valuation of injuries is in closer resemblance to that used by Fromm. This seeming lack of consistency results from the fact that T.S.C.'s injury classification (permanent total disability, permanent partial disability, and temporary injury) does not coincide with that used by the National Transportation Safety Board (serious and minor) and Fromm. Since the NTSB data base is the principal source against which these unit costs will be matched, they are derived here using the format advanced by Fromm.

It may be noted that these values differ significantly from the sample court awards outlined in this section. It should be recalled, however, that the sample does not necessarily represent the true universe and that the court awards approach suffers from the same shortcomings as with its application to valuing life, i.e., court awards may be based on the defendant's ability to pay, may involve an element of retribution against the defendant and may be tempered by community judgment.

Between interim revisions of this report, it is recommended that the unit costs of statistical injuries derived in this section be adjusted to future year dollars by the methodology outlined in the appendix to this report.

FIGURE XII

UNIT COSTS OF STATISTICAL AVIATION INJURIES
(1980 Dollars)

COST ELEMENT	NATURE AND BASIS OF COST	COST: SERIOUS INJURY	COST: MINOR INJURY
Direct Costs			
Substitute Labor, Lost Output, Income Loss, or Disability Benefits	The injured traveler is assumed to be absent from work 6 months as a result of suffering a serious injury and 1 month for a minor injury, based on analogy with Fromm.[66] If the injured traveler enjoys salary or wage continuation benefits, these costs can be equated to lost output, the cost of substitute labor, or claims paid by a third party insurer. If the employee does not enjoy salary or wage continuation benefits, or if the traveler is self-employed, these costs can be viewed as representing income loss to the injured traveler. These costs are the product of the assumed periods of disability and the annual earned income (see page 11) of the "typical" air traveler ($35,200 x (6/12) and $35,200 x (1/12)).	$17,600	$2,933
Accident Investigation Costs	Estimated accident investigation costs of government (NTSB and FAA) and private parties (air carriers, manufacturers, etc.). Estimated by analogy with such costs associated with a fatality.	10,000	10,000
Medical Expenses	Estimated medical care expenses (insured or otherwise) based on the mean of the National Safety Council's and Social Security Administration's ratios of medical and hospital costs to wage losses (.469 to 1 and .435 to 1) for 1978 work-related and total injuries, respectively.[67] Applied to above losses for substitute labor, output, income, or disability benefits and adjusted to 1980 dollars by the Consumer Price Index for Medical Care (serious injury: .452 x $17,600 x (265.7/219.4); minor injury: .452 x $2,900 x (265.7/219.4)).	9,634	1,587

Indirect Costs			
Community	Assumes the average individual contributes approximately 5% of his working time to friends and community without compensation, based on analogy with the T.S.C. study.[68] It is assumed that the value of contributed time is equal to the earnings rate. These costs are the product of the assumed periods of disability, the annual earned income of the "typical" air traveler (see page 11) and the 5% contribution factor ($35,200 x 6/12 x 5% and $35,200 x 1/12 x 5%).	880	147
Other Costs			
Lost Taxes	None or insignificant.	N/A	N/A
Private, Social and Health Insurance	Irrelevant to this valuation approach, except to the extent allowed for above.	N/A	N/A
		$38,114	$14,667
Total		or $38,000	or $15,000

Serious Injury: "Any injury which: 1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; 2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); 3) involves lacerations which cause severe hemorrages, nerve, muscle, or tendon damage; 4) involves injury to any internal organ; or 5) involves second or third-degree burns, or any burns affecting more than 5 percent of body surface." (NTSB)

Minor Injury: A nonfatal injury that is not classified as "serious."

SECTION IV - UNIT REPLACEMENT AND RESTORATION COSTS OF DAMAGED AIRCRAFT

A. Introduction

The costs of damage to aircraft in aviation accidents are borne directly by operators and indirectly by users and society in the form of higher fares and taxes. The purpose of determining such costs here is to provide measures upon which to evaluate FAA investment and regulatory programs which effect the probability of occurrence of aircraft accidents.

The National Transportation Safety Board categorizes aircraft damage as "destroyed," "substantial damage," and "minor or none." The loss of an aircraft completely destroyed can be taken as the market value of its replacement. Market values generally represent the discounted present value of the future earnings or satisfactions streams which may be derived from an asset. "Replacement cost," as used here, is that weighted cost of replacing a destroyed aircraft with another similar aircraft from the used aircraft market. Because actual market valuations are utilized, depreciation and obsolescence are implicitly taken into account. Insurance experience reveals that the average restoration cost of a substantially damaged aircraft is approximately one-third of its market or replacement cost.[69] Repair costs of aircraft incurring minor damage are negligible.

The aircraft replacement and restoration values developed in this section are weighted by the estimated relative aircraft type populations comprising the respective aircraft fleets. Because users of the data developed herein may have a need for replacement or restoration values of specific general aviation applications, the general aviation fleet is disaggregated into the following profiles: general aviation in the conventional sense (i.e., all aircraft other than air carrier and military); general aviation including air taxi other than air commuter; general aviation excluding air taxi; air taxi; air taxi other than air commuter; and air commuter. It is acknowledged that the use of weighted average values fails to account for differences in relative utilization and accident exposure of various types of aircraft within each traffic class or profile. However, lacking sufficient data upon which to reasonably determine the relative probabilities of an accident for different types of aircraft, it is assumed that the weighted average value concept will approximate the cost of replacing a completely destroyed aircraft or restoring a substantially damaged aircraft.

B. Air Carrier

The derivation of weighted unit replacement costs of air carrier aircraft is based on proceeds realized from the sale of turbofans/turbojets by certificated route and supplemental carriers for the five year period ended June 30, 1979,[70] as tabulated by the Civil Aeronautics Board from CAB Form 41, "Report of Financial and Operating Statistics for Certified Air Carriers," Schedule B-8. Proceeds generated from these sales were approximated by calendar quarter, adjusted to 1980 dollars by the Department of Labor Bureau of Labor Statistics Producer Price Index for Total Transportation Equipment, and weighted by the relative number of units of each aircraft type

within the fleets of trunk and local air carriers. The results of this analysis are outlined in Figure XIII.

C. General Aviation

The general aviation aircraft fleet encompasses a wide range of aviation applications and varies in complexity from simple gliders and balloons to four engine turbojets. It is conventionally categorized into two classifications - by aircraft type and primary use. These classifications are outlined below for cross referencing with figures appearing in this and later sections of this report.

Aircraft Type Classification:	Aircraft Type Category Number
Fixed-Wing:	
Single-engine piston, 1 to 3 seats	1
Single-engine piston, 4 seats and over	2
Twin-engine piston, under 12,500 lbs. TOGW	3
Twin-engine piston, over 12,500 lbs. TOGW	4
Multi-engine piston, over 12,500 lbs. TOGW	5
Twin-engine turboprop, under 12,500 lbs. TOGW.	6
Twin-engine turboprop, over 12,500 lbs. TOGW	7
Twin-engine turbojet/fan, under 20,000 lbs. TOGW	8
Twin-engine turbojet/fan, over 20,000 lbs. TOGW	9
Multi-engine turbojet/fan, under 20,000 lbs. TOGW.	10
Multi-engine turbojet/fan, over 20,000 lbs. TOGW	11
Rotary-Wing:	
Piston engine	12
Turbine engine	13
Other (balloons, gliders, etc.)	14

Primary Use Classification:

- Business/Executive
- Personal
- Aerial application
- Instruction
- Taxi (including commuter)
- Industrial/special
- Rental
- Other

The derivation of weighted unit replacement costs of general aviation aircraft fleet profiles, as illustrated in Figures XIV through XVII, is based on retail value data compiled by Aviation Data Service, Inc. (ADS)[71] and fleet age data.[72] The weighting factors used are based on ADS aircraft type and primary use populations with the exception of air commuter aircraft which are based on inventory statistics published by the Civil Aeronautics Board.[73] Figures XIV through XVI are denominated in 1978 dollars based on the references from which they are derived. The results of these illustrations are restated to 1980 dollars in Figure XVII, based on the adjustment methodology outlined in the appendix to this report.

Caution should be exercised in the reliance upon those profile values which are highly sensitive to air commuter aircraft values. Until recently, noncertificated commuter carriers were limited to aircraft with seating capacities of 19 or less. However, with the advent of deregulation, new rules allowing commuter aircraft to have up to 60 seats, and blossoming sales projections, a flood of new and larger aircraft is anticipated to enter the commuter market. These events are expected to have a significant impact on replacement costs of commuter aircraft.

D. Military

The derivation of the weighted unit replacement costs of military aircraft is based on data published by the Defense Marketing Service, Inc.[74] Analysis of this data yields "new" unit replacement values of $6,800,000, $1,030,000 and $3,800,000 for fixed-wing, rotary-wing and total fleet, respectively in 1980 dollars. To maintain consistency of the definition of "replacement cost" (as used in this report) between user classes, these values must be adjusted to "used" unit prices. Although it is obviously not the practice of the military to replace aircraft lost in accidents with other used aircraft, this adjustment merely provides an allowance for depreciation and obsolescence. Drawing analogies with civil aircraft, it is estimated that the typical military aircraft is 9.6 years[75] old and that the constant dollar value ratios of a 9.6 year-old aircraft to a comparable new aircraft are approximately .32 and .40 for fixed-wing and rotary-wing, respectively (derived from Figure XV). Applying these deflators to the above new unit prices yields used 1980 replacement costs of $2,200,000, $410,000 and $1,400,000 for fixed-wing, rotary-wing, and total fleet, respectively. The total fleet value is weighted by the relative inventories outlined in Figure XXIV.

FIGURE XIII

REPLACEMENT COSTS OF AIR CARRIER AIRCRAFT BY AIRCRAFT TYPE - 1980

Aircraft Type	Total Realization (1980 $)[76]	Estimated Value	No. Units Sold (7/74-6/79)[76]	Realization Per Unit	Relative Inventory[77]	Contribution
Turbofan, 4 engine, wide body	$491,641,000		24	$20,485,000	.0463	$ 948,456
Turbojet, 4 engine	17,604,000		11	1,600,000	.0036	5,760
Turbofan, 4 engine, regular body	601,565,000		152	3,958,000	.1326	524,831
Turbofan, 3 engine, wide body	82,161,000		4	20,540,000	.0867	1,780,818
Turbofan, 3 engine, regular body	257,313,000		65	3,959,000	.3730	1,476,707
Turbofan, 2 engine, wide body		$20,000,000*			.0033	66,000
Turbofan, 2 engine, regular body	354,936,000		69	5,144,000	.2390	1,229,416
Turboprop		1,269,000**			.0914	115,987
Piston		320,000**			.0241	7,712
Total					1.0000	$6,155,687 or $6,200,000

*Estimated by analogy with other wide body aircraft.
**Estimated by analogy with Figure XV, after adjustment to 1980 dollars.

FIGURE XIV

ESTIMATED RELATIVE 1978 GENERAL AVIATION POPULATIONS BY MAKE/MODEL YEAR AND AIRCRAFT TYPE CATEGORY[78]
(For Valuation Purposes)

Make/ Model Year	Aircraft Type Category*						
	1, 2, & 3	6	7	8	11	12	13
1978	.0558	.0791	—	.0725	.0824	.0552	.0847
1977	.0557	.0789	.0711	.0724	.0823	.0551	.0845
1976	.0556	.0788	.0710	.0722	.0820	.0550	.0843
1975	.0554	.0785	—	.0719	—	.0548	.0840
1974	.0551	.0781	.0704	.0716	—	.0546	.0836
1973	.0554	.0785	.0708	.0720	—	.0549	.0841
1972	.0409	.0579	.0522	.0531	.0603	.0405	.0620
1971	.0302	.0428	.0386	.0393	.0446	.0299	.0459
1970	.0279	.0395	.0356	.0362	.0412	.0276	.0423
1969	.0524	.0743	.0670	.0681	.0774	.0519	.0796
1968	.0565	.0800	.0721	.0733	.0834	.0559	.0857
1967	.0537	.0762	.0686	.0698	.0794	.0532	.0815
1966	.0644	.0912	.0822	.0836	.0951	.0637	.0977
1965	.0467	.0662	.0596	.0606	.0689	.0462	
1964	.0362		.0463	.0470	.0535	.0359	
1963	.0280		.0357	.0364	.0413	.0277	
1962	.0239		.0305		.0353	.0237	
1961	.0231		.0295		.0341	.0229	
1960	.0263		.0335		.0388	.0260	
1959	.0283		.0362			.0280	
1958	.0228		.0291			.0226	
1957	.0200					.0198	
1956	.0222					.0219	
1955	.0146					.0144	
1954	.0097					.0096	
1953	.0119					.0117	
1952	.0100					.0098	
1951	.0068					.0067	
1950	.0107					.0106	
1949						.0103	
	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

*See page 42 for description of aircraft type categories. A.T.C.'s and 5 are obsolete one-time airliners of little significance. A.T.C.'s 9 and 10 entail insignificant inventories.

FIGURE XV

1978 AGED RETAIL VALUES OF GENERAL AVIATION AIRCRAFT BY AIRCRAFT TYPE CATEGORY[79]

Make/ Model Year	Aircraft Type Category* 1	2	3	6	7	8	11	12	13
1978	$ 34,156	$ 55,587	$ 222,849	$ 872,794	—	$2,145,000	$5,800,000	$ 65,400	$ 225,000
1977	29,348	46,000	195,249	789,031	$2,640,000	1,869,000	5,300,000	53,000	177,500
1976	24,371	40,916	180,065	710,972	1,732,000	1,341,800	5,133,000	42,500	170,000
1975	19,013	37,583	141,633	632,913	—	1,248,500	—	39,200	145,000
1974	16,307	34,292	118,158	560,000	1,528,000	1,219,000	—	36,750	131,200
1973	16,038	31,167	101,950	462,750	1,460,000	1,189,000	—	40,000	116,400
1972	14,487	29,250	91,895	401,000	1,392,000	1,066,000	1,942,000	39,500	105,750
1971	14,313	28,313	82,809	350,000	1,312,728	1,175,000	1,807,000	39,500	98,750
1970	13,287	26,813	81,130	327,500	1,256,000	1,000,000	1,673,850	37,250	93,500
1969	13,250	25,357	72,304	312,500	1,208,000	976,000	1,558,200	32,300	86,250
1968	12,500	24,438	60,150	223,000	1,097,457	771,000	1,405,700	29,100	81,400
1967	11,750	21,167	53,677	209,000	994,000	742,000	1,338,800	28,500	73,000
1966	11,500	20,611	49,714	195,000	882,500	675,000	1,259,100	28,000	60,000
1965	11,250	19,194	45,750	190,000	789,825	500,000	1,104,232	28,000	
1964	10,500	18,333	42,750		697,150	475,000	942,150	26,100	
1963	10,000	17,844	37,500		565,000	550,000	869,400	25,100	
1962	10,000	17,500	33,500		511,800		774,100	24,800	
1961	9,000	15,786	32,000		434,000		722,900	23,250	
1960	9,000	15,250	29,000		406,900		722,900	22,250	
1959	8,000	14,179	26,000		361,400			21,000	
1958	7,500	13,429	24,125		357,100			20,000	
1957	7,500	11,917	22,625					19,000	
1956	6,200	11,917	21,750					18,000	
1955	6,200	11,917	21,500					18,000	
1954	4,800	11,300	20,000					18,000	
1953	4,800	11,300	20,000					15,000	
1952	4,800	10,750	20,000					15,000	
1951	4,800	10,750	20,000					15,000	
19500	4,800	10,750	17,500					15,000	
1949								15,000	

*See page 42 for description of aircraft type categories. A.T.C.'s 4 and 5 are obsolete one-time airliners of little significance. A.T.C.'s 9 and 10 entail insignificant inventories.

FIGURE XVI

1978 WEIGHTED RETAIL VALUES OF GENERAL AVIATION AIRCRAFT BY AIRCRAFT TYPE CATEGORY***
(Figure XIV* x Figure XV)

Make/ Model Year	Aircraft Type Category** 1	2	3	6	7	8	11	12	13
1978	$ 1,906	$ 3,102	$12,436	$69,018	—	$155,472	$477,913	$ 3,612	$19,053
1977	1,635	2,562	10,877	62,282	$187,779	135,223	435,928	2,922	15,003
1976	1,354	2,274	10,006	55,980	122,886	96,837	421,134	2,337	14,334
1975	1,053	2,081	7,843	49,663	—	89,796	—	2,148	12,184
1974	899	1,890	6,514	43,743	107,552	87,277	—	2,005	10,974
1973	889	1,728	5,651	36,348	103,338	85,603	—	2,195	9,791
1972	592	1,196	3,756	23,224	72,646	56,589	117,198	1,598	6,559
1971	433	856	2,503	14,990	50,662	46,126	80,641	1,182	4,529
1970	371	748	2,262	12,941	44,722	36,219	68,920	1,028	3,956
1969	695	1,330	3,792	23,224	80,896	66,483	120,664	1,677	6,864
1968	706	1,380	3,396	17,842	79,124	55,542	117,195	1,626	6,974
1967	631	1,138	2,885	15,916	68,208	51,791	106,234	1,516	5,953
1966	740	1,327	3,201	17,790	72,549	56,444	119,694	1,784	5,862
1965	525	896	2,136	12,570	47,084	30,319	76,120	1,294	
1964	380	664	1,549		32,245	22,348	50,391	936	
1963	280	500	1,050		20,198	20,000	35,941	696	
1962	239	418	801		15,616		27,313	587	
1961	208	365	739		12,800		24,654	532	
1960	236	401	762		13,648		28,038	578	
1959	227	402	737		13,077			589	
1958	171	302	550		10,402			452	
1957	150	238	452					376	
1956	137	264	482					395	
1955	90	174	314					260	
1954	46	109	193					172	
1953	57	134	237					176	
1952	48	106	198					147	
1951	33	73	136					101	
1950	51	115	187					159	
1949								154	
Weighted Composite	$14,782	$26,773	$85,645	$455,531	$1,155,432	$1,092,069	$2,307,978	$33,234	$122,036

*The relative population values actually used to derive the products in Figure XVI were extended to additional decimal positions. Therefore, minor rounding effects may result by applying the values as printed in Figure XIV.
**See page 42 for description of aircraft type categories. A.T.C.'s 4 and 5 are obsolete one-time airliners and of little significance. A.T.C.'s 9 and 10 entail insignificant inventories.
***These values are denominated in 1978 dollars. It is recommended that these values be adjusted to future dollars in accordance with the methodology outlined in the appendix to this report.

FIGURE XVII (PAGE 1 OF 3)

REPLACEMENT COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1978

Profile	A.T.C.#	Relative Inventory	Unit Value (Figure XVI)	Extension (Relative Inventory x Value)
General	1	.2866	$ 14,782	$ 4,237
Aviation	2	.5413	26,773	14,492
in the	3	.1154	85,645	9,883
Conventional	4	*	—	—
Sense	5	*	—	—
(including	6	.0137	455,531	6,241
Air Taxi	7	.0012	1,155,432	1,387
and Air	8	.0070	1,092,069	7,644
Commuter)	9	*	—	—
	10	.0000	—	—
	11	.0015	2,307,978	3,462
	12	.0199	33,234	661
	13	.0132	122,036	1,611
	14	**	—	—
	Total	1.0000		$49,618##
General	1	.2885	$ 14,782	$ 4,265
Aviation	2	.5439	26,773	14,562
Including	3	.1124	85,645	9,626
Air Taxi	4	*	—	—
Other Than	5	*	—	—
Air	6	.0121	455,531	5,512
Commuter	7	.0012	1,155,432	1,387
	8	.0070	1,092,069	7,644
	9	*	—	—
	10	.0000	—	—
	11	.0016	2,307,978	3,693
	12	.0201	33,234	668
	13	.0133	122,036	1,623
	14	**	—	—
	Total	1.0000		$48,980##

FIGURE XVII (PAGE 2 OF 3)

REPLACEMENT COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1978

Profile	A.T.C.#	Relative Inventory	Unit Value (Figure XVI)	Extension (Relative Inventory x Value)
General Aviation Excluding Air Taxi	1	.2966	$ 14,782	$ 4,384
	2	.5500	26,773	14,725
	3	.1045	85,645	8,950
	4	*	—	—
	5	*	—	—
	6	.0122	455,531	5,557
	7	.0013	1,155,432	1,502
	8	.0063	1,092,069	6,880
	9	*	—	—
	10	.0000	—	—
	11	.0016	2,307,978	3,693
	12	.0186	33,234	618
	13	.0089	122,036	1,086
	14	**	—	—
	Total	1.0000		$ 47,395##
Air Taxi	1	.0162	$ 14,782	$ 239
	2	.3052	26,773	8,171
	3	.4134	85,645	35,406
	4	*	—	—
	5	*	—	—
	6	.0528	455,531	24,052
	7	.0009	1,155,432	1,040
	8	.0262	1,092,069	28,612
	9	*	—	—
	10	.0000	—	—
	11	.0000	2,307,978	—
	12	.0551	33,234	1,831
	13	.1303	122,036	15,901
	14	**	—	—
	Total	1.0000		$115,252##

FIGURE XVII (PAGE 3 OF 3)

REPLACEMENT COSTS OF GENERAL AVIATION AIRCRAFT PROFILES - 1978

Profile	A.T.C.#	Relative Inventory	Unit Value (Figure XVI)	Extension (Relative Inventory x Value)
Air Taxi	1	.0191	$ 14,782	$ 282
Other Than	2	.3396	26,773	9,092
Air	3	.3756	85,645	32,168
Commuter	4	*	—	—
	5	*	—	—
	6	.0082	455,531	3,735
	7	.0000	1,155,432	—
	8	.0313	1,092,069	34,182
	9	*	—	—
	10	.0000	—	—
	11	.0000	2,307,978	—
	12	.0673	33,234	2,237
	13	.1589	122,036	19,392
	14	**	—	—
	Total	1.0000		$101,088##
Air	1	.0032	$ 14,782	$ 47
Commuter	2	.1500	26,773	4,016
	3	.5841	85,645	50,025
	4	*	—	—
	5	*	—	—
	6	.2541	455,531	115,750
	7	.0047	1,155,432	5,431
	8	.0032	1,092,069	3,495
	9	.0000	—	—
	10	.0000	—	—
	11	.0000	2,307,978	—
	12	.0000	33,234	—
	13	.0008	122,036	98
	14	**	—	—
	Total	1.0000		$178,862##

*Obsolete and of little significance.
**ATC 14 covers balloons, sailplanes, etc., and is not treated here.
#See page 42 for description of aircraft type categories.
##These 1978 values are restated to 1980 dollars in the summary to this section (based on the methodology outlined in the appendix to this report).

D. Summary

Unit replacement and restoration costs of damaged aircraft developed in this section are summarized in Figure XVIII in 1980 dollars. The replacement and restoration costs of general aviation aircraft, which are denominated in 1978 dollars in the text of this section, were adjusted to 1980 dollars by the methodology outlined in the appendix to this report. Between interim revisions of this report, it is recommended that the aircraft replacement and restoration cost derived in this section be adjusted to future year dollars by the methodology outlined in the appendix to this report.

FIGURE XVIII

REPLACEMENT AND RESTORATION COSTS OF DAMAGED AIRCRAFT*
(1980 Dollars)

USER CLASS	UNIT REPLACEMENT COST (DESTROYED)	UNIT RESTORATION COST (SUBSTANTIAL DAMAGE)
Air Carrier:		
Turbofan, 4 engine, wide body	$20,500,000	$6,800,000
Turbojet, 4 engine	1,600,000	530,000
Turbofan, 4 engine, regular body	4,000,000	1,300,000
Turbofan, 3 engine, wide body	20,500,000	6,800,000
Turbofan, 3 engine, regular body	4,000,000	1,300,000
Turbofan, 2 engine, wide body	20,000,000	6,700,000
Turbofan, 2 engine, regular body	5,100,000	1,700,000
Turboprop	1,300,000	430,000
Piston	300,000	100,000
Total Air Carrier	6,200,000	2,100,000
General Aviation:		
G.A. in the conventional sense (including Air Taxi and Air Commuter)	59,000	20,000
G.A. including Air Taxi other than Air Commuter	58,000	19,000
G.A. excluding Air Taxi	56,000	19,000
Air Taxi	137,000	46,000
Air Taxi other than Air Commuter	120,000	40,000
Air Commuter	213,000	71,000
Military:		
Fixed-Wing	2,200,000	730,000
Rotary-Wing	410,000	140,000
Total Military	1,400,000	470,000

*These values are based on data which may include varying degrees of avionics. but generally represent fly-away aircraft with appropriate engines, communications and navigation equipment.

SECTION V - AIRCRAFT VARIABLE OPERATING COSTS

A. Introduction

The purpose of this section is to derive estimates of aircraft operating costs; specifically, variable operating costs. Like the value of time of air travelers discussed in Section I of this report, measures of aircraft variable operating costs are useful in the evaluation of investment and regulatory programs which bear on time spent in air travel. Whereas the value of time of air travelers is a determinant in measuring the benefits or disbenefits accruing to air travelers, the variable costs of aircraft operation are determinants useful in measuring benefits/disbenefits accruing directly to aircraft operators and indirectly by users and society in the form of higher fares and taxes.

The aircraft variable operating costs outlined in this section are identified for equipment types comprising each air carrier aircraft type category and for aircraft type categories comprising the general aviation aircraft fleet. Additionally, weighted aircraft variable operating costs (per block hour and airborne hour) are derived for each air carrier aircraft type category and each general aviation aircraft fleet profile.

Published data on aircraft operating costs is commonly of two alternative formats — variable costs/fixed costs and direct costs/indirect costs. "Variable costs" are costs that fluctuate with changes in aircraft activity or usage, such as fuel, oil and maintenance. "Fixed costs" are those costs which, within a relevant range, do not fluctuate with changes in aircraft activity. Some costs are a blend of both variable and fixed costs and are commonly termed "semi-variable costs," e.g., depreciation and insurance costs which may be dependent both on the passage of time and the level of aircraft activity. "Direct costs" are costs which can be directly assigned to the operation of aircraft, such as crew, fuel, oil, and maintenance. "Indirect costs" are costs incurred not in direct relationship with aircraft operation, such as certain general and administrative overhead expenses.

Since the purpose here is to identify and quantify those costs which are a function of duration of aircraft activity, only variable costs are relevant. "Variable operating costs," as used here then, include paid flight crew, fuel, oil, and direct maintenance of airframe, avionics and engine. Insurance, hangar and tie down fees, and other flying operation expenses are excluded because they are more of a semi-variable or fixed nature. Similarly, depreciation of aircraft cost and amortization of capital leases are excluded because they are largely a function of passage of time rather than aircraft usage. Flight crew salaries and wages are included only for air carrier, air taxi, and air commuter operations in this report. It is recommended that crews for all other operations be included in occupant load factors. In this way, their time will be accorded some value - the value of time of air travelers addressed in Section I of this report.

B. Air Carrier

Figure XX summarizes variable operating costs per block hour of CAB certificated route air carriers by equipment type for calendar year 1978. This data is based on information provided to the CAB by certificated route carriers on CAB Form 41, "Report of Financial and Operating Statistics for Certificated Air Carriers[80] (part of which is reproduced in Figure XIX). Figure XXI derives weighted 1978 variable operating costs of air carrier aircraft by equipment type on block hour and airborne hour bases. These costs are restated to 1980 dollars in the Summary to this section.

C. General Aviation

Figure XXII derives variable operating costs per block hour of general aviation aircraft by aircraft type categories for calendar year 1978. For the most part, these costs are based on data compiled by Aviation Data Services, Inc.[81] In consideration of the fact that the general aviation aircraft fleet varies widely by aircraft type and primary use, Figure XXIII derives weighted 1978 variable operating costs of primary use profiles based on the respective aircraft hours flown by aircraft types within the following profiles: general aviation in the conventional sense (i.e., all aircraft other than air carrier and military); general aviation including air taxi other than air commuter; general aviation excluding air taxi; air taxi; air taxi other than air commuter; and air commuter. Refer to page 42 for a description of fleet classifications and cross-referencing with Figure XXII and XXIII. These costs are restated to 1980 dollars in the Summary to this section.

D. Military

Figure XXIV summarizes 1978 variable operating costs per block hour of military aircraft by aircraft type category. These costs were derived by analogy with comparable civil aircraft and weighted by inventories derived from data published by Defense Marketing Service, Inc.[82] As discussed in the introduction to this section, non-commercial aircraft variable operating costs, as used in this report, do not include allowances for crew salaries. Accordingly, load factors for military operations should include crews. These costs are restated to 1980 dollars in the Summary to this section.

FIGURE XXIX

PART OF SCHEDULE D-5, CAB FORM 41

FINANCIAL AND OPERATING STATISTICS FOR CERTIFICATED AIR CARRIERS

Data applicable to each aircraft type operated by carrier should be reported in separate column of this sched.

AIRCRAFT OPERATING EXPENSES Group I Air Carriers	Air Carrier ____ Operation ____ Total–All Aircraft Types ____ Qr. ☐ Yr. ☐ ____, 19__		Air Carrier ____ Operation ____ Aircraft Type ____ Qr. ☐ Yr. ☐ ____, 19__		Air Carrier ____ Operation ____ Aircraft Type ____ Qr. ☐ Yr. ☐ ____, 19__		Air Carrier ____ Operation ____ Aircraft Type ____ Qr. ☐ Yr. ☐ ____, 19__	
FLYING OPERATIONS	5100		5100		5100		5100	
Pilots and copilots	23		21		21		23	
Other flight personnel	24		24		24		24	
Trainees and instructors	26.1		26.1		26.1		26.1	
Personnel expenses	36		36		36		36	
Professional and technical fees and expenses	41		41		41		41	
Aircraft interchange charges—assoc. co's	42.7		42.7		42.7		42.7	
Aircraft interchange charges—outside	43.7		43.7		43.7		43.7	
Aircraft fuels and oils	45		45		45		45	
Rentals	47		47		47		47	
Other supplies	53		53		53		53	
Insurance purchased—general	55.1		55.1		55.1		55.1	
Employee benefits and pensions	57		57		57		57	
Injuries, loss and damage	58		58		58		58	
Taxes—payroll	68		68		68		68	
Taxes—other than payroll	69		69		69		69	
Other expenses	71		71		71		71	
Total flying operations (per sch. P-1)	5100		5100		5100		5100	
DIRECT MAINTENANCE-FLIGHT EQUIP	5200		5200		5200		5200	
Labor—flight equipment	25.0		25.0		25.0		25.0	
Flight equip. repairs—associated companies	42.0		42.0		42.0		42.0	
Aircraft interchange charges—associated co's	42.7		42.7		42.7		42.7	
Flight equipment repairs—outside	43.0		43.0		43.0		43.0	
Aircraft interchange charges—outside	43.7		43.7		43.7		43.7	
Maintenance materials—flight equipment	46.0		46.0		46.0		46.0	
Airworth. allow. provs.—airframes	72.1		72.1		72.1		72.1	
Airworth. allow. chgs.—airframes (cr)	72.2		72.2		72.2		72.2	
Airframe overhauls deferred (cr.)	72.3		72.3		72.3		72.3	
Amort. of airframe overhauls	72.4		72.4		72.4		72.4	
Airworth. allow. provs.—aircr. eng.	72.6		72.6		72.6		72.6	
Airworth. allow. chgs.—aircr. eng. (cr.)	72.7		72.7		72.7		72.7	
Aircraft eng. overhauls def (cr.)	72.8		72.8		72.8		72.8	
Amort. of engine overhauls	72.9		72.9		72.9		72.9	
Total dir. maint.—fl. equip. (to sch. P-6)	78		78		78		78	
AP. MT BURDEN–FLT. EQP. (per sch. P-6)	79.0		79		79		79	
Total flight equip. maintenance (5300)	5300		5300		5300		5300	
OBSOL. & DETERIOR'N–EXP. PARTS	7000		7000		7000		7000	
Current provisions	73.1		73		73		73	
Inventory decline credits	73.2		73		73		73	
Net obsol. & deterior'n.–exp. parts	7073.0		7073.0		7073.0		7073.0	
DEPRECIATION–FLIGHT EQUIPMENT	7000		7000		7000		7000	
Depreciation—airframes	75.1		75.1		75.1		75.1	
Depreciation—aircraft engines	75.2		75.2		75.2		75.2	
Depreciation—other flight equipment	75.4		75.5		75.5		75.5	
Total depr.—flight equip. (to sch. P-1)	75.0		75.0		75.0		75.0	
Amortization Expense — Cap. ...	78		78		78		78	
EXP. OF INTERCHANGE AIRCRAFT								
Flying operations	88.1		90.1		90.1		90.1	
Maintenance	88.2		90.2		90.2		90.2	
TOTAL AIRCRAFT OP. EXPENSES	7000.9		7000.9		7000.9		7000.9	

*Denotes inverse amount

Expenses in A/C 5300, Maintenance Burden allocated to flight equip.

Reflects the gross prov. for losses in value of exp. parts during current acct's period.
Reflects credits applicable to current period for any adjustment for excess inventory.

Schedule P-5.1 | Schedule P-5.1 | Schedule P-5.1 | Schedule P-5.1 | Schedule P-5.1

CAB Form 41
(Rev. 7-77)

FIGURE XX (PAGE 1 OF 2)

AIR CARRIER AIRCRAFT VARIABLE OPERATING COSTS# BY EQUIPMENT TYPE-1978[83]

Aircraft and Equipment Type	Crew	Fuel & Oil	Maintenance Airframe & Avionics	Maintenance Engine	Total V.O.C. Per Block Hr.
Turbofan, 4 engine, wide body					
Domestic passenger trunk	$468.79	$1,322.37	$205.57	$261.29	$2,258.02
Domestic cargo trunk	702.70	1,360.01	134.67	425.76	2,623.14
Domestic all-cargo	542.84	1,450.45	113.55	278.99	2,385.83
Int./Ter. passenger trunk	607.27	1,506.67	186.81	234.06	2,534.81
Int./Ter. cargo trunk	699.19	1,682.50	190.69	229.66	2,802.04
Int./Ter. all-cargo	592.45	1,595.89	178.63	244.73	2,611.70
Turbojet, 4 engine					
Domestic passenger trunk	415.38	826.87	83.09	115.71	1,441.05
Domestic all-cargo trunk	289.70	921.03	123.50	42.43	1,376.66
Turbofan, 4 engine, regular body					
Domestic passenger trunk	398.66	676.81	105.53	90.23	1,271.23
Domestic cargo trunk	425.27	700.89	103.49	83.34	1,312.99
Domestic all-cargo	395.25	738.85	175.78	143.51	1,453.39
Int./Ter. passenger trunk	506.75	782.53	111.23	95.60	1,496.11
Int./Ter. cargo trunk	487.10	718.54	95.34	94.57	1,395.55
Int./Ter. all-cargo	498.29	877.97	175.65	108.16	1,660.07
Turbofan, 3 engine, wide body					
Domestic passenger trunk	432.78	895.65	145.37	209.84	1,683.64
Int./Ter. passenger trunk	476.63	1,069.07	179.80	219.85	1,945.35

FIGURE XX (PAGE 2 OF 2)

AIR CARRIER AIRCRAFT VARIABLE OPERATING COSTS# BY EQUIPMENT TYPE-1978[83]

Aircraft and Equipment Type	Crew	Fuel & Oil	Maintenance Airframe & Avionics	Maintenance Engine	Total V.O.C. Per Block Hr.
Turbofan, 3 engine, regular body					
Domestic passenger trunk	$325.34	$512.51	$ 68.00	$ 51.52	$ 957.37
Domestic cargo trunk	253.94	501.20	88.96	88.40	932.50
Domestic passenger local service	389.60	527.40	66.25	106.09	1,089.34
Int./Ter. passenger trunk	406.29	593.40	81.64	49.12	1,130.45
Int./Ter. passenger/cargo trunk	402.82	760.66	103.31	182.73	1,449.52
Domestic passenger Alaskan trunk	302.07	524.68	97.84	60.12	984.71
Turbofan, 2 engine, wide body					
Domestic passenger trunk	427.97	683.27	106.33	46.59	1,264.16
Turbofan, 2 engine, regular body					
Domestic passenger trunk	297.53	344.48	68.08	35.51	745.60
Domestic passenger local service	239.24	356.59	74.47	61.47	731.77
Domestic passenger Alaskan	173.92	413.12	39.07	.00	626.11
Domestic passeger Hawaiian	336.38	427.42	119.38	81.92	965.10
Turboprop, 2 engine					
Domestic passenger local service	146.24	117.59	71.17	57.22	392.22
Domestic passenger others	75.86	83.57	113.82		273.25
Piston, 2 engine					
Alaskan passenger	33.30	24.72	45.16		103.18

#As defined on page 52.

FIGURE XXI (PAGE 1 OF 3)

WEIGHTED VARIABLE OPERATING COSTS# OF AIR CARRIER AIRCRAFT - 1978[84]

Aircraft and Equipemnt Type	Activity		Variable Operating Cost		Dollar Extensions	
	Block Hrs.	Airborne Hrs.	Block Hr.	Airborne Hr.##	Block Hr.	Airborne Hr.
Turbofan, 4 Engine, Wide-Body						
Domestic passeger trunk	135,814	122,355	$2,258.02	$2,543.44	$ 306,670,728	$ 311,202,601
Domestic cargo trunk	8,530	7,061	2,623.14	3,175.19	22,375,384	22,420,017
Domestic all-cargo	8,708	7,585	2,385.83	2,764.54	20,775,808	20,969,036
Int./Ter. passenger trunk	235,693	219,863	2,534.81	2,737.96	597,436,973	601,976,100
Int./Ter. cargo trunk	22,444	20,534	2,802.04	3,091.20	62,888,986	63,474,701
Int./Ter. all-cargo	24,093	21,883	2,611.70	2,936.20	62,923,688	64,252,865
Total	435,282	399,281	$2,465.23*	$2,715.62*	$1,073,071,567	$1,084,295,320
Turbojet, 4 Engine						
Domestic passenger trunk	24,470	21,693	$1,411.05	$1,630.97	$ 34,528,394	$ 35,380,632
Domestic all-cargo trunk	9,350	8,047	1,376.66	1,612.06	12,871,771	12,972,247
Total	33,820	29,740	$1,401.54*	$1,625.85*	$ 47,400,165	$ 48,352,879
Turbofan, 4 Engine, Regular Body						
Domestic passenger trunk	625,158	549,831	$1,271.23	$1,460.06	$ 794,719,604	$ 802,786,250
Domestic cargo trunk	66,611	58,948	1,312.99	1,520.53	87,459,577	89,632,202
Domestic all-cargo	41,233	35,212	1,453.39	1,715.99	59,927,630	60,423,440
Int./Ter. passenger trunk	277,158	254,273	1,496.11	1,682.33	414,658,855	427,771,096
Int./Ter. cargo trunk	13,354	12,11[illegible]	1,395.55	1,627.03	18,636,175	19,716,350
Int./Ter. all-cargo	38,889	33,670	1,660.07	2,169.82	64,558,462	73,057,839
Total	1,062,403	944,052	$1,355.38*	$1,560.71*	$1,439,960,303	$1,473,387,177

FIGURE XXI (PAGE 2 OF 3)

WEIGHTED VARIABLE OPERATING COSTS# OF AIR CARRIER AIRCRAFT - 1978[84]

Aircraft and Equipment Type	Activity		Variable Operating Cost		Dollar Extensions	
	Block Hrs.	Airborne Hrs.	Block Hr.	Airborne Hr.##	Block Hr.	Airborne Hr.
Turbofan, 3 Engine, Wide-Body						
Domestic Passenger Trunk	637,297	556,591	$1,683.64	$1,949.68	$1,072,978,721	$1,085,174,341
Int./Ter. Passenger Trunk	58,609	53,281	1,945.35	2,151.42	114,015,018	114,629,809
Total	695,906	609,872	$1,705.68*	$1,967.30*	$1,186,993,739	$1,199,804,150
Turbofan, 3 Engine, Regular Body						
Domestic passenger trunk	2,705,828	2,277,633	$ 957.37	$1,147.12	$2,590,478,552	$2,612,718,367
Domest cargo trunk	5,478	4,856	932.50	1,051.94	5,108,235	5,108,221
Domestic passenger local service	33,036	28,164	1,089.34	1,344.34	35,987,436	37,861,992
Int./Ter. passenger trunk	88,303	75,992	1,130.45	1,329.70	99,822,126	101,046,562
Int./Ter. passenger/cargo trunk	7,217	6,496	1,449.52	1,621.78	10,461,186	10,535,083
Domestic passenger Alaskan trunk	26,495	23,385	984.71	1,121.06	26,089,891	26,215,988
Total	2,866,357	2,416,526	$ 965.67*	$1,155.99*	$2,767,947,426	$2,793,486,213
Turbofan, 2 Engine, Wide Body						
Domestic passenger trunk	12,171	10,332	$1,264.16*	$1,557.08*	$ 15,386,091	$ 16,087,751
Turbofan, 2 Engine, Regular Body						
Domestic passenger trunk	722,041	586,072	$ 745.60	$ 927.67	$ 538,353,770	$ 543,681,412
Domestic passenger local service	929,263	762,942	731.77	898.46	680,006,786	685,472,869
Domestic passenger Alaskan	19,023	16,470	626.11	744.26	11,910,491	12,257,962
Domestic passenger Hawaiian	39,148	29,193	965.10	1,340.67	37,781,735	39,138,179
Total	1,709,475	1,394,677	$ 741.78*	$ 918.17*	$1,268,052,782	$1,280,550,422

FIGURE XXI (PAGE 3 OF 3)

WEIGHTED VARIABLE OPERATING COSTS# OF AIR CARRIER AIRCRAFT - 1978[84]

Aircraft and Equipment Type	Activity		Variable Operating Cost		Dollar Extensions	
	Block Hrs.	Airborne Hrs.	Block Hr.	Airborne Hr.##	Block Hr.	Airborne Hr.
Turboprop, 2 Engine						
Domestic passenger local service	283,899	232,895	$ 392.22	$ 497.88	$ 111,350,866	$ 115,953,763
Domestic passenger others	61,590	50,442	273.25	352.99	16,829,468	17,805,522
Total	345,489	283,337	$ 371.01*	$ 472.09*	$ 128,180,334	$ 133,759,285
Piston, 2 Engine						
Alaskan Passenger	11,845	11,845	$ 103.18*	$ 105.02*	$ 1,222,167	$ 1,243,962
Grand Total	7,172,748	6,099,662	$1,105.32*	$1,316.62*	$7,928,214,574	$8,030,967,159

As defined on page 52.
V.O.C. per airborne hour = (D.O.C. per airborne hour/D.O.C. per block hour) x V.O.C. per block hour
*These 1978 values are restated to 1980 dollars in the summary to this section (based on the methodology outlined in the appendix to this report).

FIGURE XXII (PAGE 1 OF 2)

GENERAL AVIATION AIRCRAFT VARIABLE OPERATING COSTS# BY AIRCRAFT TYPE CATEGORY-1978

Aircraft Type	Crew	Fuel & Oil[85]	Maintenance[85] Airframe & Avionics	Maintenance[85] Engine	Total V.O.C. Per Hour Air Taxi/Air Commuter	Total V.O.C. Per Hour Other
Fixed-Wing						
Single-engine piston, 1-3 seats (A.T.C. 1)	##	$ 9.93	$ 3.56	$ 2.68	$36.17	$ 16.17
Single-engine piston, 4 + seats (A.T.C. 2)	##	12.41	5.59	3.94	41.94	21.94
Twin-engine piston, < 12,500 lbs. TOGW (A.T.C. 3)	##	25.12	24.60	16.42	99.14	66.14
Twin-engine piston, ≥ 12,500 lbs. TOGW (A.T.C. 4)	*	*	*	*	*	*
Multi-engine piston, ≥ 12,500 lbs. TOGW (A.T.C. 5)	*	*	*	*	*	*
Twin-engine TP, ≤ 12,500 lbs. TOGW (A.T.C. 6)	##	54.61	43.49	33.86	277.96	131.96
Twin-engine TP, ≥ 12,500 lbs. TOGW (A.T.C. 7)	##	198.25	152.86	27.44	524.55	378.55
Twin-engine TJ/F, < 20,000 lbs. TOGW (A.T.C. 8)	##	252.05	88.54	73.74	653.33	414.33
Twin-engine TJ/F, ≥ 20,000 lbs. TOGW (A.T.C. 9)	##	354.10	120.25	83.51	796.86	557.86

FIGURE XXII (PAGE 2 OF 2)

GENERAL AVIATION AIRCRAFT VARIABLE OPERATING COSTS# BY AIRCRAFT TYPE CATEGORY-1978

Aircraft Type	Crew	Fuel & Oil[85]	Maintenance[85]		Total V.O.C. Per Hour	
			Airframe & Avionics	Engine	Air Taxi/Air Commuter	Other
Multi-engine TJ/F, < 20,000 lbs TOGW (A.T.C. 10)	**	**	**	**	**	**
Multi-engine TJ/F, ≥ 20,000 lbs TOGW (A.T.C. 11)	##	$388.26	$214.55	$246.67	$1,238.48	$849.48
Rotary-Wing						
Rotary piston (A.T.C. 12)	##	13.73	18.64	6.55	58.92	38.92
Rotary turbine (A.T.C. 13)	##	22.44	26.06	29.73	118.23	78.23
Other (A.T.C. 14)	***	***	***	***	***	***

As defined on page 52.
The following hourly allowances for crew salaries were made for Air Taxi and Air Commuter operations: ATC 1 - $20.00; ATC 2 - $20.00: ATC 3 - $33.00; ATC 6 - $146.00; ATC 7 - $146.00; ATC 8 - $239.00; ATC 9 - $239.00; ATC 11 - $389.00; ATC 12 - $20.00; ATC 13 - $40.00.
* Obsolete one-time airliners of little significance.
** No inventory.
*** A.T.C. 14 covers sailplanes, balloons, etc. Cost data is insignificant and is ignored here.

FIGURE XXIII (PAGE 1 OF 3)

WEIGHTED VARIABLE OPERATING COSTS# OF GENERAL AVIATION AIRCRAFT PROFILES - 1978[86]

Aircraft Type Category Air Taxi/Commuter	Aircraft Type Category Other	Variable Operating Costs (Fig. XXII)	GA in the Conventional Sense (Including Air Taxi and Air Commuter) Hours	GA in the Conventional Sense (Including Air Taxi and Air Commuter) Extension	GA Including Air Taxi Other Than Air Commuter Hours	GA Including Air Taxi Other Than Air Commuter Extension
1		36.17	29,832	$ 1,079,023	28,776	$ 1,040,828
	1	16.17	8,574,775	138,654,112	8,574,775	138,654,112
2		41.94	944,476	39,611,323	860,306	36,081,234
	2	21.94	18,590,357	407,872,433	18,590,357	407,872,433
3		99.14	1,379,986	136,811,812	1,313,089	130,179,644
	3	66.14	5,057,256	334,486,912	5,057,256	334,486,912
4		*	*	*	*	*
	4	*	*	*	*	*
5		*	*	*	*	*
	5	*	*	*	*	*
6		277.96	338,373	94,054,159	43,099	11,979,798
	6	131.96	1,332,640	175,855,174	1,332,640	175,855,174
7		524.55	6,498	3,408,526	**	**
	7	378.55	169,699	64,239,556	169,699	64,239,556
8		653.33	115,656	75,561,534	113,128	73,909,916
	8	414.33	633,088	262,307,351	633,088	262,307,351
9		796.86	6,972	5,555,708	6,972	5,555,708
	9	557.86	442,782	247,010,367	442,782	247,010,367
10		**	**	**	**	**
	10	**	**	**	**	**
11		1,238.48	**	**	**	**
	11	849.48	89,479	76,010,621	89,479	76,010,621
12		58.92	170,517	10,046,862	170,517	10,046,862
	12	38.92	903,995	35,183,485	903,995	35,183,485
13		118.23	690,053	81,584,966	689,295	81,495,348
	13	78.23	725,264	56,737,403	725,264	56,737,403
14		***	***	***	***	***
	14	***	***	***	***	***
Total			40,201,698	$2,246,071,327	39,744,517	$2,148,646,752
Weighted V.O.C.			$55.87##		$54.06##	

FIGURE XXIII (PAGE 2 OF 3)

WEIGHTED VARIABLE OPERATING COSTS# OF GENERAL AVIATION AIRCRAFT PROFILES - 1978[86]

Aircraft Type Category Air Taxi/Commuter	Aircraft Type Category Other	Variable Operating Costs (Fig. XXII)	GA Excluding Air Taxi Hours	GA Excluding Air Taxi Extension	Air Taxi Hours	Air Taxi Extension
1		36.17			29,832	$ 1,079,023
	1	16.17	8,574,775	$ 138,654,112		
2		41.94			944,476	39,611,323
	2	21.94	18,590,357	407,872,433		
3		99.14			1,379,986	136,811,812
	3	66.14	5,057,256	334,486,912		
4		*			*	*
	4	*	*	*		
5		*			*	*
	5	*	*	*		
6		277.96			338,373	94,054,159
	6	131.96	1,332,640	175,855,174		
7		524.55			6,498	3,408,526
	7	378.55	169,699	64,239,556		
8		653.33			115,656	75,561,534
	8	414.33	633,088	262,307,351		
9		796.86			6,972	5,555,708
	9	557.86	442,782	247,010,367		
10		**			**	**
	10	**	**	**		
11		1,238.48			**	**
	11	849.48	89,479	76,010,621		
12		58.92			170,517	10,046,862
	12	38.92	903,995	35,183,485		
13		118.23			690,053	81.584,966
	13	78.23	725,264	56,737,403		
14		***			***	***
	14	***	***	***		
Total			36,519,335	$1,798,357,414	3,682,363	$447,713,913
Weighted V.O.C.			$49.24##		$121.58##	

FIGURE XXIII (PAGE 3 OF 3)

WEIGHTED VARIABLE OPERATING COSTS# OF GENERAL AVIATION AIRCRAFT PROFILES - 1978[86]

Aircraft Type Category Air Taxi/Commuter	Other	Variable Operating Costs (Fig. XXII)	Air Taxi Other Than Air Commuter Hours	Air Taxi Other Than Air Commuter Extension	Air Commuter Hours	Air Commuter Extension
1		36.17	28,776	$ 1,040,828	1,056	$ 38,196
2		41.94	860,306	36,081,234	84,170	3,530,090
3		99.14	1,313,089	130,179,644	66,897	6,632,169
4		*	*	*	*	*
5		*	*	*	*	*
6		277.96	43,099	11,979,798	295,274	82,074,361
7		524.55	**	**	6,498	3,408,526
8		653.33	113,128	73,909,916	2,528	1,651,618
9		796.86	6,972	5,555,708	**	**
10		**	**	**	**	**
11		**	**	**	**	**
12		58.92	170,517	10,046,862	**	**
13		118.23	689,295	81,495,348	758	89,618
14		***	***	***	***	***
Total			3,225,182	$350,289,338	457,181	$97,424,578
Weighted V.O.C.			$108.61##		$213.10##	

\# As defined on page 52.
\## These 1978 values are restated to 1980 dollars in the summary to this section (based on the methodology outlined in the appendix to this report).
* Obsolete one-time airliners of no great consequence
** No inventory.
*** A.T.C. 14 covers sailplanes, balloons, etc. Cost data is insignificant and is ignored here.

FIGURE XXIV

MILITARY AIRCRAFT VARIABLE OPERATING COSTS* BY EQUIPMENT TYPE - 1978[87]

Aircraft and Equipment Type	Fuel & Oil	Maintenance: Airframe & Avionics	Maintenance: Engine	Total**	Relative Inventory	Contribution
Fixed Wing						
Multi-engine TJ/F	$932.00	$129.00	$153.00	$1,214.00	.0531	$ 64.46
Twin-engine TJ/F	534.00	91.00	53.00	678.00	.2708	183.60
Single-engine TJ/F	343.00	83.00	30.00	456.00	.1079	49.20
Turboprop	101.00	67.00	54.00	222.00	.0885	19.65
Piston	25.00	25.00	20.00	70.00	.0365	2.56
Rotary-Wing	22.00	26.00	30.00	78.00	.4432	34.57
Total						$354.04**

* As defined on page 52.
**These 1978 values are restated to 1980 dollars in the summary to this section (based on the methodology outlined in the appendix to this report).

D. Summary

Aircraft variable operating costs, as defined and derived in this section, are summarized in Figure XXV after being adjusted from 1978 to 1980 dollars by the methodology outlined in the appendix to this report. Between interim revisions of this report, it is recommended that the aircraft variable operating costs derived in this section be adjusted to future year dollars by the methodology outlined in the appendix to this report.

FIGURE XXV

AIRCRAFT VARIABLE OPERATING COSTS
(1980 Dollars)

USER CLASS AND AIRCRAFT TYPE/PROFILE	PER BLOCK HOUR	PER AIRBORNE HOUR
Air Carrier:		
TF, 4 engine, wide body	$4,327	$4,767
TJ, 4 engine	2,483	2,880
TF, 4 engine, regular body	2,295	2,643
TF, 3 engine, wide body	2,897	3,341
TF, 3 engine, regular body	1,641	1,964
TF, 2 engine, wide body	2,155	2,655
TF, 2 engine, regular body	1,219	1,508
TP, 2 engine	546	694
Piston, 2 engine	136	139
Total	1,871	2,229
General Aviation:		
GA in the conventional sense (including Air Taxi and Air Commuter)		$ 81
GA including Air Taxi other than Air Commuter		79
GA excluding Air Taxi		73
Air Taxi		163
Air Taxi other than Air Commuter		145
Air Commuter		278
Military:		
Fixed-Wing:		
Multi-engine TJ/F		$2,339
Turn-Engine TJ/F		1,319
Single-engine TJ/F		872
Turboprop		360
Piston		97
Rotary-Wing		113
Total		661

SECTION VI - APPENDIX: ADJUSTMENT METHODOLOGY TO UPDATE CRITICAL VALUES

The values developed in this report are expected to change with the passage of time, basically because of anticipated price and income level changes and, to a lesser extent, state-of-the-art improvements resulting from future theoretical and empirical research. This report will be revised periodically to account for such changes and advancements. Between revisions, users may desire to adjust the 1980 values developed herein to future year dollars based on the methodology outlined in this section.

Value of Time of Air Travelers

In Section I it is recommended that the hourly earnings rate of the "typical" air traveler be maintained as the basis for valuing the time of air travelers. This rate may be adjusted to future year dollars by the Department of Labor Bureau of Labor Statistics Index of Adjusted Hourly Earnings. Expressed in another way,

$$(AEI_f/AEI_b) \times T_b = \text{Adjusted Value of Time of Air Travelers}$$

where AEI_f and AEI_b are the adjusted hourly earnings indices of the future year and base year, respectively, and T_b is the value of time of air travelers in the base year ($17.50 in 1980).

Considering the imprecise art of valuing time, whether by reference to an earnings rate or some other basis, it is recommended that adjusted values of time be rounded to the nearest $.50 to avoid specious accuracy.

Value of a Statistical Life

The value of a statistical life derived in Section II consists of: (1) active compensation to the family - risk premium plus insurance compensation; and (2) passively absorbed societal losses - lost taxes, lost charity, employer losses and accident investigation costs. Since it is reasonable to perceive these components as being largely functions of earnings, the value of a statistical life developed in this report may be adjusted to future year dollars by the Department of Labor Bureau of Labor Statistics Index of Adjusted Hourly Earnings. Expressed in another way,

$$(AEI_f/AEI_b) \times L_b) = \text{Adjusted Value of a Statistical Life}$$

where AEI_f and AEI_B are the adjusted hourly earnings indices of the future year and base year, respectively, and L_b is the value of a statistical life in the base year ($530,000 in 1980).

To avoid specious accuracy, it is recommended that adjusted values of life be rounded to the nearest $10,000.

Unit Costs of Statistical Aviation Injuries

The unit costs of statistical aviation injuries derived in Section III consist of: the costs of substitute labor, lost output, income loss, or disability benefits; accident investigation costs; medical expenses; and lost charitable contributions to the community. Other than medical expenses, these costs are largely a function of earnings. Accordingly, the unit costs of statistical aviation injuries developed in this report may be appropriately adjusted to future year dollars by the Department of Labor Bureau of Labor Statistics Consumer Price Index for Medical Care and Index of Adjusted Hourly Earnings. Expressed in another way,

$$((CPI\text{-}M_f/CPI\text{-}M_b) \times M_b) + ((AEI_f/AEI_b) \times O_b) = \text{Adjusted Unit Costs of Statistical Aviation Injuries}$$

where $CPI\text{-}M_f$ and $CPI\text{-}M_b$ are the consumer price indices for medical care for the future year and base year, AEI_f and AEI_b are the adjusted hourly earnings indices for the future year and base year, M_b is medical expenses in the base year ($9,634 for a serious injury and $1,587 for a minor injury in 1980), and O_b is all other identified costs of injuries in the base year ($28,480 for a serious injury and $13,080 for a minor injury in 1980).

To avoid specious accuracy, it is recommended that adjusted costs of injuries be rounded to the nearest $1,000.

Unit Replacement and Restoration Costs of Damaged Aircraft

In the absence of a more specific index, it is suggested that the Department of Labor Bureau of Labor Statistics' Producer Price Index for Total Transportation Equipment be used to adjust aircraft replacement and restoration costs in Section IV to future year dollars. Expressed in another way,

$$(PPI\text{-}TE_f/PPI\text{-}TE_b) \times (REP_b \text{ or } RES_b) = \text{Adjusted Unit Replacement/Restoration Cost of a Damaged Aircraft}$$

where $PPI\text{-}TE_f$ and $PPI\text{-}TE_b$ are the Producer Price Indices for Total Transportation Equipment for the future year and base year, REP_b is the unit replacement cost of a destroyed aircraft in the base year, and RES_b is the unit restoration cost of a substantially damaged aircraft in the base year.

To avoid specious accuracy, it is recommended that adjusted aircraft replacement and restoration costs be rounded to the nearest $100,000 for air carrier and military aircraft and $1000 for general aviation aircraft.

Aircraft Variable Operating Costs

Aircraft variable operating costs, as defined and developed in Section V, consist of fuel, oil, direct maintenance of airframe, avionics and engine, plus flight crew salaries and wages for air carrier, air taxi and air commuter operators. Other costs of a semi-variable or fixed nature are considered irrelevant for the purposes of measuring the cost of delay or the savings of

reduced operating time. The costs of aviation fuel and oil may be readily adjusted to future year dollar levels by reference to data published by the FAA Office of Environment and Energy. Since maintenance costs are generally labor intensive, the Department of Labor Bureau of Labor Statistics' Index of Adjusted Hourly Earnings may be thought of as an appropriate means by which to adjust direct maintenance costs and allowances for flight crew salaries. Expressed in another way,

$$((F_f/F_b) \times FO_b) + ((AEI_f/AEI_b) \times M_b) = \text{Adjusted Aircraft Variable Operating Costs}$$

where F_f and F_b are the prices of aviation gas/jet fuel per gallon in the future year and the 1978 base year, AEI_f and AEI_b are the adjusted hourly earnings indices for the future year and base year, and FO_b and M_b are the fuel and oil and maintenance costs, respectively, per hour of aircraft operation in the base year.

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